DOCUMENT RESUME

ED 287 707 SE 048 663

TITLE	Approaches to Teaching Energy. Energy and Ourselves/Energy for the Consumer. Children's Learning in Science Project.
INSTITUTION	Leeds Univ. (England). Centre for Studies in Science and Mathematics Education.
PUB DATE	Jun 87
NOTE	159p.; Contains a set of unmounted slides for use with lesson one; these slides are not available from EDRS. For related publications, see SE 048 661-665.
AVAILABLE FROM	Children's Learning in Science Project, Centre for Studies in Science and Mathematics Education, The University of Leeds, Leeds LS2 9JT England, United Kingdom.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Concept Formation; *Energy Conservation; *Energy Education; Energy Management; Foreign Countries; Learning Strategies; Learning Theories; Process Education; *Science Activities; Science Curriculum; Science Education; *Science Instruction; Scientific Concepts; Secondary Education; *Secondary School Science; Teaching Methods; Visual Aids
IDENTIFIERS	Childrens Learning in Science Project; *Constructivism; United Kingdom

ABSTRACT

During the period 1984-1986, over 30 teachers from the Yorkshire (England) region have worked in collaboration with the Children's Learning in Science Project (CLIS) developing and testing teaching schemes in the areas of energy, particle theory, and plant nutrition. The project is based upon the constructivist approach to teaching. This guide focuses on teaching about energy. The program starts with considerations about children's early ideas about human energy, and is called "Energy and Ourselves." These ideas are extended into a consideration of energy in the home and is entitled "Energy for the Consumer." Sequence of the lessons follows this plan: (1) orientation; (2) eliciting students' ideas; (3) restructuring, modifying and extending ideas; (4) application of ideas; and (5) review of change of ideas. Materials developed and field tested by a group of 12 science teachers dealt with such energy concepts as transfer and transformation, conservation, degradation, dissipation, quantification, and transfer efficiency. The guide contains lesson plans, pupil worksheets and sections of explanatory text. (A third program, "Energy for Citizenship," is discussed only in terms of rationale.) (TW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

Children's Learning in Science Project

Approaches to Teaching Energy

Energy and ourselves

Energy for the consumer

These materials were produced by the Energy Working Group
of the Children's Learning in Science Project

June 1987

Centre for Studies in Science and Mathematics Education
University of Leeds
Leeds LS2 9JT

© University of Leeds, 1987

The pupil material in this package (the white sheets in Section Four) may be copied for classroom use.

The Energy Working Group

These teaching materials have been developed and trialled by a group of science teachers working in collaboration with the Children's Learning in Science Project from September 1984 to July 1986. The people involved in their production were:

Dennis Alanach	Bruntcliffe High School, Leeds
Mike Anderson	John Smeaton Community High School, Leeds
Angela Brook	Children's Learning in Science Project (group convenor)
John Davidson	Bruntcliffe High School, Leeds
Alan Dow	St. Joseph's College, Bradford
Rosalind Driver	Children's Learning in Science Project
Steven Gater	Batley Boys' School, Kirklees
David Hughes	John Smeaton Community High School, Leeds
David Kent	Abbey Grange Church of England High School, Leeds
David Powell	Tong School, Bradford
Beverley Price	Abbey Grange Church of England High School, Leeds
Peter Wells	Boston Spa Comprehensive School, Leeds

The Children's Learning in Science Project

The Children's Learning in Science Project was funded throughout this phase of its work (1984-1986) by the Department of Education and Science and the School Curriculum Development Committee through the Secondary Science Curriculum Review.

Project team:	Rosalind Driver	Project Director
	Angela Brook	Project Officer
	Kate Johnston	Teacher Associate 1985-1986
		Project Co-ordinator 1986 -
	Richard Needham	Teacher Associate 1986-1987
	Valerie Oldham	Project Co-ordinator 1985-1986
	Phil Scott	Associated Teacher 1984-1986
	Peter Wells	Teacher Associate 1986-1987
	Maura Crosland	Project Secretary
	Sharon Crossley	Project Secretary
	Elisabeth Stephens	Project Secretary
Steering Committee:	M. Capey	D.E.S. (Chairman)
	M. Michell	S.S.C.R.
	J. Kirkham	S.S.C.R.
	T. Burdett	H.M.I.
	A. Clegg	H.M.I.
	R. Senior	Calder High School
	C. Wood-Robinson	University of Leeds
	J. West	Leeds L.E.A.

Contents

Acknowledgements

SECTION 1 **Introduction**

1.1 About this package 1

1.2 What is energy? 3

1.3 Why is there a problem? 6

1.4 An approach to teaching and learning 7

SECTION 2 **The schemes in overview**

2.1 General outline 8

2.2 Implications of a citizen's understanding: concepts and contexts 10

SECTION 3 **Teaching strategies**

3.1 Setting up groups 15

3.2 Working in groups 16

3.3 Class discussion work 18

3.4 Written work 20

3.5 Time 21

3.6 Assessment 22

SECTION 4 **The schemes in action**

Energy and Ourselves 26

Energy for the Consumer 75

SECTION 5 **Some reactions to the schemes**

5.1 From the teachers 125

5.2 From the students 127

5.3 From you 129

Notes 130

Further reading 132

Acknowledgements

All members of the project team have had some part to play in the discussion and development of the work described here. Particular thanks are due to Sharon Crossley and Elisabeth Stephens for their patience and good humour through many redrafts.

We would also like to express our appreciation to the Headteachers, staff and students of all of the schools involved in the trialling of materials, and to our local education authorities; without their co-operation and help the work would not have been possible.

We would also like to thank Dudley Hind from Calversyke School, Bradford and Robin Thompson and Malcolm Cox from Boston Spa Comprehensive School, Leeds for their help in trialling lessons.

British Gas PLC and The Electricity Council have been helpful in providing facsimile fuel bills and other resources.

Finally, we would like to thank members of the Steering Committee for their helpful comments on the draft, and Tony Wallis, Robin Millar, John Ogborn, Paul Black, Paolo Guidoni and Poul Thomsen for useful discussions during the development of the schemes.

SECTION 1
Introduction

1.1 About this package

The materials presented here reflect the developmental programme which was mapped out by the Children's Learning in Science Project energy working group (1) when we began to address the problems associated with teaching energy.

Early on in the work of the group, in Autumn 1984, we considered what, in our view, a future citizen would need to know about energy. Our work was also informed by international research literature, and by our own surveys which document the ideas about energy which young secondary school students bring to the learning situation. Focussing on these two considerations - starting point and intended end point - we mapped out a developmental sequence for the teaching of energy during the secondary school years.

The programme starts with children's early ideas about energy, which tend to focus on the notion of human energy and 'energeticness'. These ideas are extended into a consideration of energy in domestic contexts, and then into consideration of broader societal issues concerned with energy supply and demand. This plan was divided into three schemes of work:

Energy and ourselves	10-12 years
Energy for the consumer	13-15 years
Energy for citizenship	14-16 years.

The first two of these schemes have been developed and trialled and are presented in this package, which is divided into four sections. The rest of this section focusses on the rationale for the development of the schemes. The importance of the energy concept for citizenship is discussed, and we present the perspective on teaching and learning which is implicit in our curriculum materials.

The second section starts from a general outline of the teaching schemes, and goes on to focus on the learning contexts which have been selected to promote the development of understanding important aspects of the energy concept. Section Three has been written as a result of our experiences of using the schemes, and offers some suggestions for the use of open-ended teaching strategies.

Section Four contains detailed lesson notes for each of the two schemes. The notes include outline activities for each lesson with suggested apparatus and materials. Student worksheets are included and may be copied for use in classrooms. In addition, we have made notes on how children in the trial classes responded to the activities. We hope that this will prove useful to those who are using the materials for the first time.

We realise that the approach used in the lessons is demanding both for the students and for the teacher, but the schemes have been designed and trialled with a range of secondary school classes, and we find that the methods do work. Students are interested and engaged, and, from our experience, the end result is a group of students who are better equipped to use what they have learned both in and out of school, and who are aware of just how much progress they have made in their ideas about energy.

Although these schemes reflect a great deal of work on the part of the group in devising, trialling and revising the materials, we would encourage others not to view this document as the 'definitive' approach to teaching energy, but rather as one possible approach. We hope that other teachers will use it as a framework within which they can explore issues and develop new teaching strategies which are appropriate to the needs of their own students.

1.2 What is energy?

Students coming into secondary school will already be familiar with the word energy. They may have encountered the word already in primary school, and they will almost certainly have seen it used in advertising and the media in connection with foods (some of which claim to 'replace lost energy') and fuels (fuel companies have slogans such as 'energy for life' and 'energy is our business'). They are also likely to use it in their own speech, mostly in connection with human 'energeticness':

When i go for a ron, louse all my energy

~~Sterent~~ energy gives you strenth

I am out of energy

Kicking is using energy

Typical responses for 11 year olds asked to write sentences about energy.

In fact it is likely that most 11 year old students do not differ greatly in their use and understanding of the term energy from the majority of adults. It is not that they have no understanding of the term 'energy' - the term does have a meaning for them; it is however a lay meaning.

This lay meaning might include:

- a close association between notions of energy and other terms such as force, power, energy etc. Hence words may appear to be used in ambiguous ways.

- a notion of energy as substantive (e.g. plants get their energy from the sun, and this makes them grow - energy changes into plant matter).

- a tendency to see energy as a fuel-like entity which is used up. Thus when a sliding object has stopped its energy has 'gone'.

- a view of energy as something which 'makes things happen', leading to a one-way view of energy changes, and energy being seen as a causal agent which is expended. This is in conflict with a view of energy transfers in interacting systems where the total energy is the same before and after transfer occurs.

From the point of view of scientists and technologists 'energy' has a more precise meaning, as described here by Feynman (2):

> 'there is a certain quantity, which we call energy, which does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity that does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same.'

Indeed energy is an important concept, though an elusive one, in our understanding of most scientific and technological processes from photosynthesis to steel making. Scientists' understanding and control of these processes often involves sophisticated theoretical quantitative models involving energy. The scientific meaning of energy is thus abstract and essentially quantitative.

Only a minority of school students, however, will continue in a scientifically oriented career. Most are unlikely to need to talk about exothermic reactions, Gibbs Free energy or even work done (in the scientific sense!). On the other hand all of them are likely to be concerned about such things as fuel bills, petrol consumption, healthy eating and weight-watching.

ED287707

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Rosalind Driver

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

To understand these matters we suggest that students need to have an understanding of energy that goes beyond the lay meaning with all its vagueness and ambiguity. Yet we argue that the scientific meaning is not particularly helpful for most people in the domain of everyday problems. Instead what is needed is a citizen's meaning: an understanding of energy which, without emphasising the abstract, formal mathematical relations is none the less quantitative and which will enable students to consider issues such as transferring energy effectively and getting value for what they pay for.

This raises an issue for us concerning our aims in science teaching and in particular the teaching of energy. Are we educating students in order to promote a scientific understanding of ideas about energy (which may appear to be emphasised in current school courses and exam syllabuses) or are we educating them in order that they can act effectively and responsibly in their own lives in their homes and in their local environment? We would argue that, if our prime concern is the latter, then the question remains as to how this can best be done.

These teaching schemes involve an approach which has been developed and trialled by a number of science teachers and researchers. The aim of the lessons is to promote an understanding of energy through a consideration of relevant and realistic contexts which students will find useful in their everyday life.

Also we hope that this programme of work will not be an obstacle to those students who wish to follow a more academic science course in the future - indeed it can lay a useful conceptual foundation for such studies. Thus we do not envisage the development of a citizen's understanding of energy taking place at the expense of a more scientific understanding.

1.3 Why is there a problem?

Traditionally energy has been introduced in secondary school in a short unit of a few weeks as part of a general science or physics course. It is often taught, tested and considered 'done'. The definitions are given (e.g. energy is the ability to do work), the units (joules, kilojoule, kWh, even calories and therms) are explained, the circuses of experiments are performed and written up and students start a new topic. The whole concept of energy is self-contained (in a similar way to a topic on 'metals' or 'insects' or 'the solar system').

This process suggests an implicit view of the teaching and learning process as one in which information is transmitted from the teacher to a passive learner, who absorbs it. Although it might be acknowledged that children do have ideas about energy before they are taught, the influence of these prior ideas on their learning is not usually considered.

Research on students' learning in the area of energy suggests that there are various problems which may arise from this approach:

- Students may not distinguish between everyday informal meanings for 'energy' and the scientific meaning, resulting in a confused understanding (3). A problem with traditional teaching is often that the teacher assumes the student arrives with an open mind and no prior knowledge. This, we have already suggested, is not the case. All students have meanings for the term 'energy' which have been useful to them and which may be firmly established. During traditional teaching new ideas are assimilated to these prior ideas producing unintended meanings (4) (5).

- Students may have difficulty making sense of fundamental scientific ideas associated with the energy concept in current teaching, and what is taught is thus not necessarily learned. Very few 15 year old students for example use the idea of energy conservation even after being taught (6) (7).

1.4 An approach to teaching and learning

The schemes are based on a view of learning as an active process in which individuals make sense of experiences in terms of their prior knowledge. This view has a number of implications for how we think about learning in classrooms (8).

a) What students learn depends not only on their classroom experiences but also on what they already know.

It is impossible for a teacher to predict exactly what observations students will make about given phenomena even if they are carefully guided. Furthermore, the interpretations which students make of their observations also depends on the particular mental model with which they are operating (9).

b) Learning involves the active construction of meaning.

It is not enough for a teacher to deliver information, the learner must actively restructure his or her ideas. This implies that learners must ultimately be responsible for their own learning; they must make links with their prior knowledge - no one else can do it for them!

c) Understanding and belief

A student may be able to understand scientific ideas about energy, but may find it difficult to integrate them with his or her prior ideas. Thus learners may be able to operate successfully with the new ideas presented by the teacher, whilst still not believing them.

d) Shared meanings

The idea that learning involves individuals making sense of their environment suggests that a class of thirty students are likely to have thirty different views of the world! However, although some students may develop idiosyncratic ideas about similar phenomena, since many of their experiences are shared, they tend also to have shared meanings for and interpretations of their experiences. These shared meanings, because they are reinforced by social interaction, and they seem to 'make sense' of things around us, are difficult to change.

SECTION 2
The schemes in overview

2.1 General outline

The view of learning described in Section One has a number of implications for the design of materials for use in classrooms:

a) Students' prior ideas
We acknowledge that students have ideas about energy before they experience formal teaching, and attempt to take these into account explicitly. Thus the schemes have been developed to start with children's lay understandings, helping them to modify and restructure their ideas towards more sophisticated understandings.

b) Learning as an active process
Learning is seen as a process in which students make sense of new experiences (including classroom experiences) in terms of their existing knowledge and understanding. The teaching methods are designed to give students opportunities to construct their ideas for themselves. Rather than relying on didactic teaching methods or a 'recipe following' style of practical work, the emphasis is on the students being actively involved in their own learning and being aware of their own responsibility for it. The teacher's role changes from being the provider of information to being the manager of the learning environment.

c) Meaningful contexts for learning
Whilst we hope that some students may construct a general understanding from the particular learning situations others who are unable to do so may still have learned something of specific use (e.g. understanding fuel bills).

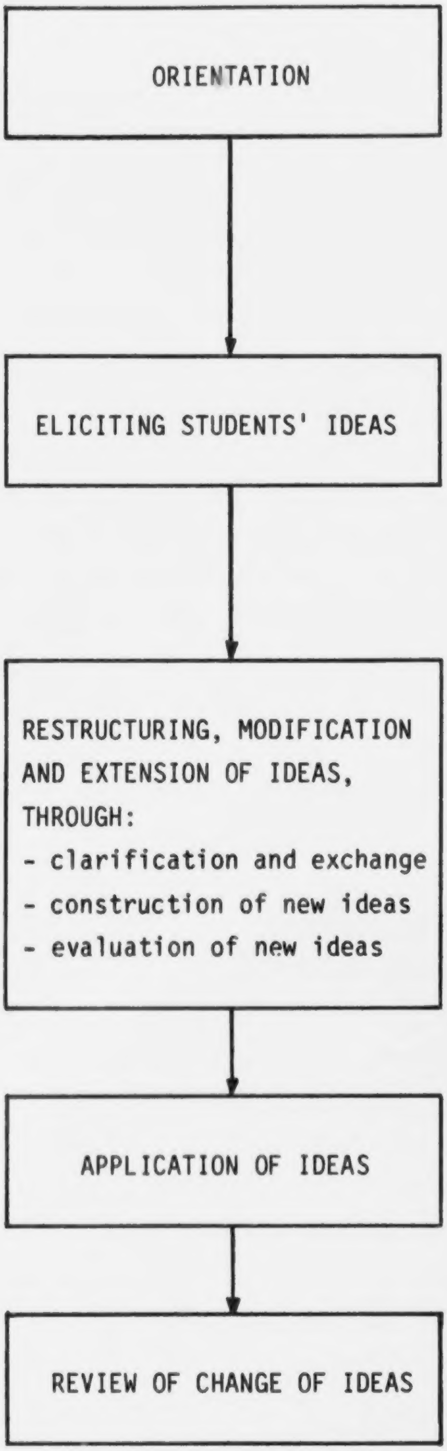
Each of the schemes follows the same general pattern, shown on the right hand side of this page. The topic begins with an orientation phase which sets the scene and helps students to realise the importance of the topic in their own lives.

This is followed by activities which encourage students to make their current ideas explicit to the teacher, to the class, but most importantly to themselves. It is hoped that, during this process, they become aware that others might have ideas which differ from their own, but which need to be listened to and evaluated.

The process of restructuring, modification and extension of ideas is based on the need for students to make sense of new ideas for themselves. For this reason, priority is given to opportunities for students to clarify and exchange ideas with their peers and to construct new ideas, and time to evaluate their newly constructed ideas.

This evaluation process continues in a further application phase of work, where students are asked to use their new ideas in familiar and new contexts.

Finally, students consider how far they have moved in their own thinking, and are encouraged to recognise that this is not the end of the road as far as learning about energy is concerned.


ORIENTATION
ELICITING STUDENTS' IDEAS
RESTRUCTURING, MODIFICATION AND EXTENSION OF IDEAS, THROUGH:
- clarification and exchange
- construction of new ideas
- evaluation of new ideas
APPLICATION OF IDEAS
REVIEW OF CHANGE OF IDEAS

2.2 Implications of a citizen's understanding: concepts and contexts

Whilst we acknowledge that the scientific meaning of energy is an abstract one, knowledge of which is unlikely to be useful in the everyday lives of most students, we also recognise that aspects of this scientific view, set in familiar contexts, might be useful to students in interpreting their experiences.

For this reason, both schemes are structured around practical questions and issues rather than around activities to demonstrate general scientific principles. This does not mean, however, that the schemes do not introduce students to basic concepts; the following aspects of energy feature in the schemes:

- energy transfer - and transformation
- energy conservation
- energy degradation
- energy dissipation
- energy quantification
- efficiency of energy transfers.

Several of the above could be taken as useful starting points for teaching and learning about energy, although there are problems associated with each of them. Energy transformations, for example, are often sufficiently dramatic and important to students (and adults!) to make this a popular choice as an introduction to energy. However, the idea that there is a 'something' which keeps popping up in different disguises can easily be debased into a generalised explanation for just about everything, and if it is made more meaningful by combining it with energy conservation (as happens in much current practice) real problems arise.

Laboratory demonstrations of conservation are impossible without a prior understanding of quantification of energy, which brings its own problems (for example, students may find it difficult to accept that the amount of energy transferred by keeping a three kilowatt electric fire on for one hour is the same as that transferred to a person who rises from sea level to the top of Everest).

The lessons presented here are built around contexts which are familiar to children. It is thus inappropriate to describe the sequencing of different aspects of the energy concept, since each may appear several times during the topic. However, here is a guide to the approach to each of the ideas covered:

a) Energy transfer and transformation

Energy transfer is a key feature of both schemes, since when energy is transferred, interesting things happen. Students are asked to consider where the energy comes from, what happens to it and where it goes to. However, little emphasis is given to the 'forms' of energy involved. Where students themselves introduce new terminology such as 'heat energy', 'light energy', movement energy' etc., these are accepted and used, but questions focus on 'where' rather than 'what'.

b) Energy conservation

Children tend to think of energy as something which gets used up (when a fuel burns it gives off heat which disappears; when a moving object stops it has used up its energy) (10). If children are to appreciate energy conservation, they need also to address the issues of degradation and dissipation. In these schemes this is done by taking situations where these changes are perceptually obvious, and so conservation is made to seem reasonable. The schemes adopt a 'you can't get something for nothing' approach, and 'it must have gone somewhere, where is it now?' is a frequent question.

c) Energy degradation and dissipation

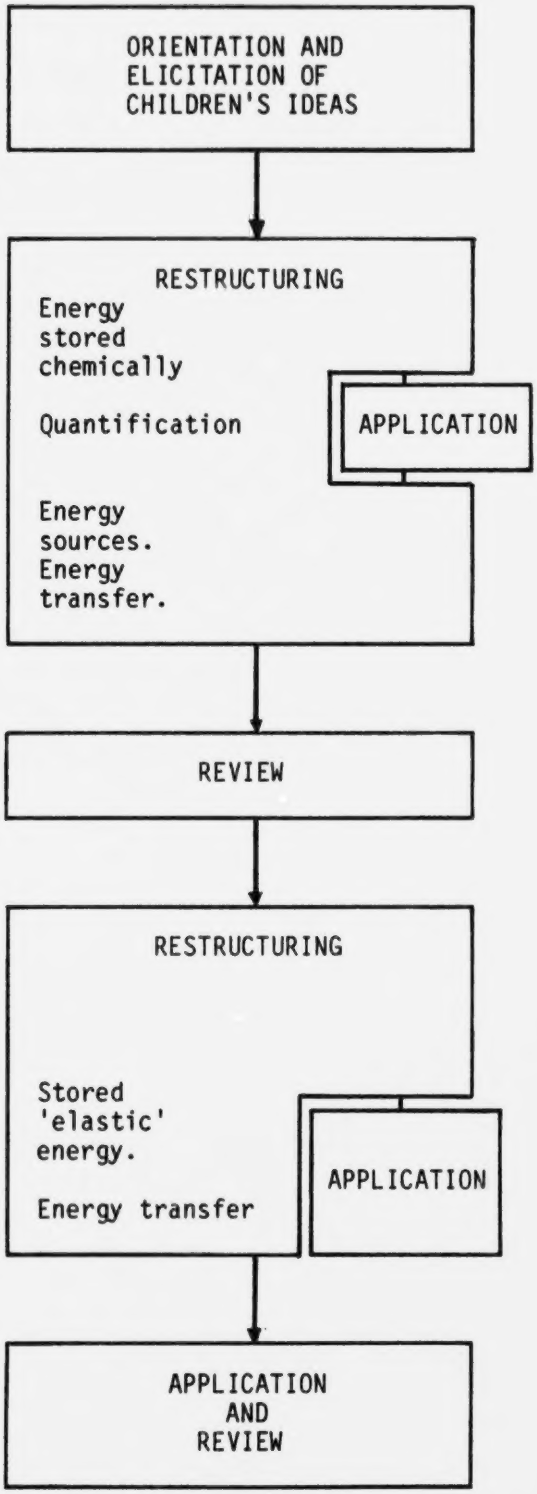
These are approached in terms of usefulness and wastage, particularly in the 'Energy for the consumer' scheme, where an exercise is included in which students are asked to minimise dissipation and explain their techniques for doing so.

d) Energy quantification and efficiency of transfers

In 'Energy and ourselves', energy is introduced as quantifiable in terms of the energy in foods (as marked on packets). In 'Energy for the consumer', students are introduced to the metering of gas and electricity, and the reading and interpretation of fuel bills. They also consider efficiency in terms of the amount of energy paid for and the (smaller) amount which actually does what is intended.

The schemes use a common unit of energy; the joule, and where other units are introduced, these are related to the joule. Quantification is not introduced in a formal way through the concept of work, but in a direct experiential way by considering the amounts of energy supplied by different foods and fuels.

The contexts in which these aspects are introduced in the 'Energy and ourselves' and 'Energy for the consumer' schemes are shown on the following pages, mapped onto the general outline discussed previously.


ORIENTATION AND ELICITATION OF CHILDREN'S IDEAS
RESTRUCTURING
Energy stored chemically
Quantification
APPLICATION
Energy sources. Energy transfer.
REVIEW
RESTRUCTURING
Stored 'elastic' energy.
Energy transfer
APPLICATION
APPLICATION AND REVIEW

LESSON ONE
What do we already know about energy? Writing statements about energy, then categorising them: 'agree'/'disagree'/'not sure'.

LESSON TWO
Do we need energy to live and to be active? Where does it come from? Do we get different amounts from different foods? How can we measure it?

LESSON THREE
How much energy do we need?

LESSON FOUR
Why is the sun's energy important? Tracing fuel and food energy to the sun.

LESSON FIVE
Review of ideas encountered so far. How else can we store energy (as well as food and fuel)?

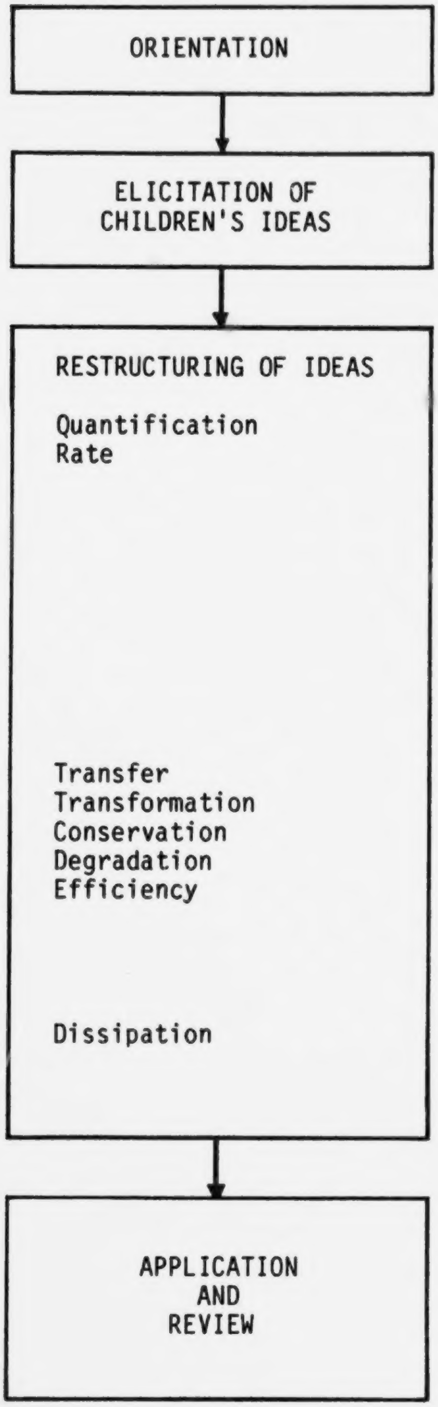
LESSON SIX
Can inanimate objects have energy? Energy increases with height, force does not increase.

LESSON SEVEN
Measuring stored energy: marbles and sand tray experiment.

LESSON EIGHT
What happens to our energy when we are lifted? Where does energy go to when we fall?

LESSONS NINE AND TEN
Review of ideas encountered so far (including review of statements and categorisation). Design of 'machine' to store energy, then release it to do something useful. Consideration of degradation and friction.

Energy for the consumer: an overview


ORIENTATION
ELICITATION OF CHILDREN'S IDEAS
RESTRUCTURING OF IDEAS
Quantification
Rate
Transfer
Transformation
Conservation
Degradation
Efficiency
Dissipation
APPLICATION AND REVIEW

LESSON ONE
Reasons for people's choice of fuels. Energy 'content' as one of several reasons.

LESSON TWO .
Elicit children's ideas about energy transfer in their own domestic contexts:
- where it comes from
- where it goes to
- comparing amounts.

LESSON THREE
Energy can be measured: metering electricity.
Energy can be transferred at different rates.
Power is the rate at which we 'use' energy: watts as rating on domestic equipment.

LESSON FOUR
What do we pay for when we buy energy?
Household fuel bills: reading meters and bills.
Cost of heating different types of house.
Joule as a common energy unit.

LESSONS FIVE AND SIX
What happens when we 'use' energy?
Energy transfer in domestic devices.
Notation introduced to illustrate where energy goes. Heat energy often a by-product when energy is transferred. Not all supplied energy does what we want it to do.

LESSON SEVEN
Energy tends to 'spread out'.
Dissipation experiment.

LESSON EIGHT, NINE AND TEN
How do we keep as much energy as possible where we want it?
Designing and making a model energy-efficient house.
The energy crisis and energy conservation.
Review of ideas encountered so far.

SECTION 3

Teaching strategies

The kinds of strategies which, we suggest, may help students to modify their ideas about energy are relatively unusual in secondary science classrooms. The purpose of this section is to draw on the experiences of some of the teachers who were involved in the development and trialling of the schemes to outline some of the issues which we felt to be important (11).

3.1 Setting up groups

The schemes are based on pairs and groups of students working together throughout the whole of the sequence of lessons. We found groups of four to be an optimum size, since it allows for work in pairs followed by group work, and it is small enough for all students to participate.

We tended to allow the students to select their own groups. Students who are already happy at working with each other will probably work together more effectively than if they had been kept apart. (Particularly, single-sex groups tend to form.) Two pairs of friends brought together into a four are likely to benefit from having one person 'on their side' and also from having to make a case to 'sell' their viewpoint to the other pair. There are obviously going to be some students who teachers will not wish to have working together, but disruptive students have to be put somewhere and it might be argued that if they sit together then they are only going to disrupt themselves!

3.2 Working in groups

What do you do if the groups, or a group, are unproductive (e.g. do not talk about the topic under consideration)? Probably there is not a great deal than can be done, on the spur of the moment, to remedy the situation. First check that the task has been understood; tasks that we may find easy may still present problems to children. It may be that the stimulus material was uninteresting, in which case an alternative task or list of stimulus questions might work. We found that students need a clearly perceived focus of attention or task if discussion was to serve any useful purpose. This can be achieved in a number of ways, many of which are utilised in the schemes:

- a list of questions to answer
- a sorting or categorising activity followed by a justification of decisions
- production of a poster or OHP transparency
- preparation of a consensus viewpoint
- a design for an experiment
- formulating a list of rules for a 'fair test'
- building a model

Group discussion may be slow at first because it is an activity which is not often part of the repertoire of the students, at least in science lessons, or is not traditionally used in the school. Our experience is that it is worth persisting; it is a worthwhile activity and students will learn to enjoy and benefit from it as their confidence increases.

What can you do if one or two students are ignored by the rest of the group? Two approaches were attempted by those of us who trialled the material. Firstly we gave all members of the group an individual 'job' within the group. Performing the task would require some degree of co-operation.

24

For example, one student could record answers to questions, one could prepare a summary for a plenary session, others could make a poster. Another strategy used was to divide the group into pairs. Each pair had to tackle the task and then the pairs come together to achieve a consensus or an 'agree to differ' situation.

What can you do if one student is dominant or disruptive? This is a difficult problem - especially if the dominant student is also the source of many of the group's ideas. Students must be made aware of the ground rules of discussion; everyone is expected to make a contribution but not dominate. Again, assigning tasks may help. A more radical solution is ask the group what they are going to do about the disruptive/dominant members. 'How are you going to get X to keep quiet and stop messing around?' With some help from the teacher, groups of students can become powerful socialising agencies.

What can you do if group discussion results in a great deal of noise? Simple - just listen to how much noise half a dozen teachers can make in the staffroom at lunchtime and accept it! Students actively involved in their own learning will, at times, be loud. What is important is to assess what is productive noise and what is not and to ensure that students can hear others in their groups. Obviously you have to retain control and this can be difficult if you constantly need to move from group to group to keep them going by adopting a catalytic role; if students engage with the tasks, you can be free to deal with the group that looks as though it might need your attention!

The working environment helps! If furniture can be moved then you can take advantage of this and distribute the furniture to make the groups self-contained and independent. We found that the arrangement of furniture was very important being either a positive or negative influence. Discussion is promoted by arranging the students within their groups so they can face each other; discussion is severely inhibited if the students are in rows and have to twist round uncomfortably to make contact. (Even if the laboratory is organised around fixed benches, you can ask students to sit around the benches rather than along them.)

3.3 Class discussion work

Reporting back to the class

We feel that a major feature of group discussion activities is that students must be given the opportunity to discuss, justify or present their viewpoint to a wider audience, usually the rest of the class. This illustrates the variety of viewpoints that do exist, acknowledges the status of the students' ideas, i.e. 'this is as far as our thinking has gone at the moment', and allows for your intervention to clarify student ideas and suggest alternatives of your own.

We all find presenting our ideas to our peers unnerving, and students are no exception; they may find standing up and talking to the rest of the class difficult at first, especially if it is not a familiar activity outside science. However, you can help by managing the activity so as to reduce their feelings of insecurity.

We found that it was a good idea to make the groups aware early on in the lesson that they would be asked to provide a representative to speak to the rest of the class. The focus of the presentation and the time for which the student is expected to speak can also be outlined at this point (about two minutes is usually long enough!). It helps if the 'volunteer' has something to illustrate the ideas of the group (something to point to - a poster or a model), and it is less threatening to present a group's view than a personal one. Certainly for the first few sessions, other members of the group should be asked to join the speaker to give moral support and help to answer questions about the presentation.

As in the case of group discussion work, the position of the furniture is important in determining the success of the session. If you can, clear a space and arrange the stools into a semicircle so that everyone can see and hear the speaker.

Your role in the report back is a matter of choice. On the first few occasions you may need to encourage the speakers and ask the rest of the class to listen to and respect (as well as evaluate and question) the ideas of each of the groups in turn.

However, as students become more accustomed to this activity, you may be able to assume a less dominant role, perhaps choosing to sit with the class, and leaving the presenter largely in control of his or her audience. If you can become one of the audience, you have the opportunity to ask questions of the student in a non-threatening way, and thus to introduce issues which the rest of the class may pick up and explore.

'Teacher-led' discussion

At particular stages in each of the schemes, the lesson plans suggest that you 'lead a class discussion'. This can be viewed as being less formal than a report back session, but the ideas discussed should still come predominantly from the students. The following suggestions might help you to avoid closed discussion:

- rearrange the chairs as suggested for reporting back sessions

- use first names when asking students for contributions, and thank them for sharing their ideas

- allow time for students to respond to questions. Be prepared to allow about half a minute for students to respond before you intervene.

- encourage students to talk to each other, not to you, but ensure that they listen to each other's views.

- try to restrict your comments to points of clarification. If you feel you need to ask a question to encourage students to move on in their thinking, try to make it open (i.e. one that cannot be answered with one word), and allow students to respond without interrupting or rephrasing.

3.4 Written work

We suggest in the schemes that students keep records of their work on paper in a number of ways:

> Worksheets are provided in the schemes. Some are intended for individual and homework use, but most for use by pairs or groups of students. The latter are designed to provide a focus for discussion, and students are encouraged to talk about their ideas before they are committed to paper. Even where worksheets are meant to be used during a practical activity, they focus on questions for discussion rather than on practical procedures.
>
> Posters are produced by the groups at intervals throughout the schemes. These provide a very 'visible' record of the students' ideas at different points during the sequence of lessons and are useful in helping them to review the ways in which their ideas might have changed. You will need plenty of wall space for this! It also helps if all the lessons are in the same laboratory, but alternatively you may be able to put some work on the corridor walls outside, so that it is fairly easily accessible.
>
> We found that we had doubts about the wisdom of putting 'wrong' ideas up on display. However, right or wrong, the posters show what the students think, and they do recognise, from the posters, that their ideas are shifting. Displays can be headed to indicate their status, e.g. IDEAS ABOUT ENERGY IN 4B AT THE BEGINNING OF THE ENERGY TOPIC.
>
> Collage work takes a lot of time, but it can be worth it! Our original idea was to build into each scheme opportunities to produce collages including the work of each group throughout the topic, together with newspaper and magazine articles which the group considered relevant. (Wallpaper lining paper works well as a basis for the display; groups typically need two to three metres.) However, we found that this activity meant that the scheme needed to be extended by one or two lessons, and remember that students need plenty of notice to start scouring the popular press!

Notes in exercise books are given little emphasis in the schemes. It may be that you feel comfortable with group records of work, kept in folders, but it is more likely that you would prefer individuals to have a record of the lessons. We suggest that when notes are given, they are generated as far as possible by the class, so that you have a 'consensus so far'. The notes written down at the end of the topic could also focus on what the students feel they have learned, emphasising the change in their ideas.

Homework suggestions are made periodically through both schemes. In some cases worksheets are provided which can be copied for individual use. Written work at home is intended to help students to think through their ideas and make them explicit to themselves and to you. You may feel that it is inappropriate to mark such work 'right' or 'wrong', and comments such as 'that is an interesting point' or 'I'm not sure I know what you mean, could you say a bit more?' might prove more useful.

You might also try asking students to produce extended pieces of imaginative writing, such as 'What would it be like to live in a world without electricity?'. Although students may not associate such work with science, it will help them to think through their ideas, and could also give you some feedback as to the progress they are making. More information about the use of written work in science is available from the National Writing Project (12).

3.5 Time

The schemes may appear to be costly in terms of the time involved (ten double lessons for 'Energy and ourselves', eleven for 'Energy for the consumer'). Discussion work is particularly demanding, but we would suggest that, if students are to make sense of and develop difficult concepts for themselves, they need both a range of experiences and opportunities to think through their ideas. Talking with their peers and sharing ideas makes an important contribution to this process.

Aspects of the energy concept which are developed in these schemes may help students in their understanding of other science topics (13), and you may find that spending longer on energy means that students will be able to draw on these ideas more easily later in their secondary school careers. From our experience in using these teaching strategies, we would also suggest long-term benefits from students becoming more aware of what the learning process involves and being prepared to acknowledge their own responsibility for learning.

3.6 Assessment

The teaching approaches described in this section have been designed to help learners to develop their ideas through interaction with their peers and with their environment. Traditional assessment, undertaken to determine the extent to which students have reached certain externally defined end-points, may still be necessary. However, we would suggest that it may be more appropriate to assess the progress that each individual has made, involving him or her in the assessment process.

The main aim of the scheme is to promote conceptual understanding, and this may thus be a primary focus of assessment. However, although the emphasis has not been on skills and processes, we would suggest that these are developed in parallel (14). Additional criteria could include:

- developing student confidence (in tackling novel situations, oral work, social and communication skills)
- encouraging positive interaction and feedback between students and student to teacher
- developing skills and attitudes which are transferable across the curriculum
- promoting conceptual understanding
- giving students an awareness of their own 'learning goals' and achievements.

Assessment techniques

Current practice employs a range of techniques, each with problems, but survives because both advantages and disadvantages are reasonably well understood. In turning to new forms of assessment to meet new needs, the risk factor involved in experimentation must be very carefully considered. A pragmatic approach is probably to use currently accepted assessment techniques and adopt new techniques when confidence in them rises. We have no 'tried and tested' solutions, but we can make a few suggestions:

- tests with open ended answers; allowing the student to express as fully as possible his/her own thoughts/ideas
- tests to be written by the children themselves, with answers; to encourage children to suggest their own applications/situation
- concept mapping; students linking ideas to give an overall picture of understanding
- pre- and post-testing; more formal but with opportunities for children to compare and discuss their own performances
- problem solving activities; application of knowledge and understanding to familiar or more demanding situations
- open book examinations; testing the ability of children to use acquired knowledge and understanding under less pressure
- oral questioning; time consuming, subjeccive but often very revealing.

When and what?

No easy answers here either! Current trends towards profiling appear to indicate a move towards capturing more data on students' performance and attitudes, but these continuously applied schemes make great demands on student and teacher time. One solution might be to couple your assessment of the student with providing him or her with suitable means to assess his or her own learning. Thus the learner is regularly supplied with positive feedback on progress.

SECTION 4

The scheme in action

A note on the content of this section

This section includes detailed lesson plans for each of the schemes: 'Energy and ourselves' and 'Energy for the consumer'. These consist of outline activities for each double (60 - 80 minutes) lesson (both for students and teacher) with suggested apparatus and materials. There is space on each lesson plan for you to add notes of your own.

Timings have not been included in the lesson plans themselves, but where we feel it is important to devote a substantial amount of time to a particular activity, we have mentioned this in the more extended notes which accompany each lesson. These notes also include a brief outline of our intention for the lesson, practical notes drawn from the experience of the teachers involved in the trialling, and some examples of students' work. We found that the types of ideas and conceptual issues that arise do tend to be predictable, so our notes should give you some idea of what to expect.

Student worksheets are included and these may be copied as required. Some worksheets are intended for use with groups of four students (although you may find you need to provide several copies per group for ease of reading), some with pairs, others are for individual use. This is made clear in the lesson notes, and in the reference list at the end of each scheme. This list also itemises the equipment and materials required for each lesson. Much of the equipment required for the lessons is already available in school. Additional material (shoe boxes, for instance) is inexpensive, but needs to be organised well in advance.

Suggestions for homeworks are made at the end of some lessons. None of these are necessary for the flow of the topic, but you may like to select some of them for use with your class. They range from ongoing activities such as collecting material for collage work to specific tasks based on discussion and practical work during lessons. Although less easy to monitor, homework time can also be allocated to students thinking through their ideas, without necessarily producing a written outcome.

Energy and ourselves

Energy and ourselves

1

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What do we know about energy?		Individually, students write down five statements which include the word energy (defining energy, describing energy, giving examples of energy).	for each student: 5 strips of paper for each group: poster paper for mounting statements glue wall space!	
		As a group, the students then discuss all of the ideas (20 in all) and to categorise them as 'agree with', 'disagree with' or 'uncertain' (if no consensus can be reached).	OHP with initial instructions: 'What does energy mean to you?'	
	Supervise pinning mounted statements to the wall. Lead discussion, asking students to suggest how the statments could be grouped. Various categories might be suggested, including 'machines', 'human activity', 'energy sources' etc.			
		Students work in groups of 4, colour-coding their statements. The posters are then returned to the wall display area so that the proportions of different coloured stickers can be seen quite clearly. It is probable that the commonest type of sticker will be some association with human energy.	coloured pens or stickers for each group	
	Suggest to the class that this aspect of energy will be considered first, returning to other ideas later.			

Homework suggestion: Students could be asked to begin work on a collage about energy (energy saving, energy crisis, energy supply etc.) and continue to collect articles for display (magazine cuttings etc.) as homework during the topic. Remember that students will need to have several lessons set aside for constructing the collage if it is to be a success and you need to add these on to the topic.

The scheme in action: orientation and eliciting ideas

1

Aims of the lesson

The intention here is to give students an opportunity to make their ideas about energy explicit to themselves and to share their ideas with their peers. It also serves as an introduction to group work; students become aware that other members of the group might have different ideas from their own.

Timings

Most classes seem to spend about 30 minutes on writing and sorting the statements into agree/disagree/not sure.

Practical notes

The initial grouping can either be into three 'piles':

Agree	Disagree	Not sure
....	....	....
....	....	....
....		....
....		
....		
....		

or in a continuum:

Agree ....
....
Not sure ....
....
Disagree ....

The categories ('human' energy, machines, sources etc.) should come from the class if possible, although you can make suggestions if you feel they are missing something obvious!

Spread the posters of statements around the room for ease of viewing, and remember that they need to be taken down for revision later, so try not to make the fixing too permanent!

Students' response

Most of the statements generated by younger students tend to focus on energy required for human activity, or energy in living things, as shown here in lists of statements produced by a class of 11 year olds.

Agree:

In engines there is energy
Horses need energy to gallop
Energy is needed to push and pull
Human beings have energy
When you swim you use energy
Gymnnasts need energy
Gas fires need energy
Most runners have energy
Energy is something which you use when you do most kinds of sports
Most sports need energy
Athletes have energy
Race dogs have energy
Animals have energy
We can't live without energy

Disagree:

Sometimes you can run out of energy

Not sure:

Energy is not to be seen or heard
You can not see energy
Energy is an invisible substance

Agree:

You need energy to ride a bike
Everybody has energy
Athletes have lots of energy
If you run for a long time you will lose your energy
A greyhound needs energy in a race
You need energy to walk
Racehorses need energy in the Grand National when they run
The car was stuck in the snow and they needed energy to push it out
I use a lot of energy when I play netball
Food gives you the energy you need
You need a lot of energy to do sport
Joggers need energy to keep running

Not sure:

My dog has a lot of energy he runs around all the time
You need energy to lift heavy weights
You need energy to play games
Energy gives you power

Indeed, the assumption that this is likely to be the case determined the focus of the rest of the scheme. Some groups may argue vehemently about the 'correctness' of their statements, but at this stage most students will agree with most of the statements generated by their peers. The disagreements tend to come up in later review lessons!

What does energy mean to you ?

1

Write down five statements including the word energy.

Put these statements into three groups:

- all agree with
- all disagree with
- not sure

Energy and ourselves

2

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
Do we use energy to live and be active?	Introduce the idea that different activities involve different amounts of energy.	Students follow the circus of simple physical activities, e.g. running on the spot, squat thrusts, press-ups etc. For each activity they decide (in pairs) whether energy is involved.	Instruction cards for 'physical activities'.	
Where does the energy come from?	Lead a class discussion about whether energy is involved, and where the energy comes from. Burn a food sample to get some idea of how much energy it has. Then introduce the next activity, handing out food samples to students, and discussing how they might decide how much energy different foods have.		food samples: lard, nuts margarine, cornflakes, dry bread, dried fruit	
Do different foods contain different amounts of energy?		Working in pairs, students put the food samples in order in terms of the energy they think will be released in burning. Students then burn foods and revise their ideas as/if necessary. Pairs combine to form four, and reach consensus on ordering. Representatives from some of the groups report back to the class, explaining how they decided which foods had most energy.	for each group: tongs balance tin lids heat resistant mats spoons spatulas goggles.	
How can we measure the energy in food?	Act as chairperson, drawing together ideas and helping the class to reach a consensus. If you have time, you could ask children to burn a peanut under a fixed volume of water and calculate the energy released from the peanut from the change in water temperature. Show food packets with energy values to the students.		food packets.	

Homework suggestion: Students could be asked to find out the energy supplied by some common foods (e.g. bread, yoghurt, breakfast cereal etc.) and fill in the worksheet 'How much energy do different foods have?' They should also be asked to bring in empty food packets for display in lesson three.

The scheme in action : restructuring

2

Aims of the lesson

This lesson is intended to extend students' notion of energy involved in human activity to energy supplied by food, and to introduce quantification an energy units (through food 'energy values').

Timings

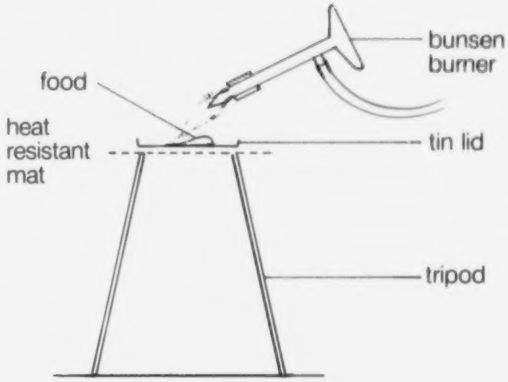
More time should be devoted to thinking in this lesson than to doing. The food burning experiment typically takes 15-20 minutes, and the rest of the lesson can be spent predicting which food they expect to have most energy, deciding on the criteria they will use to compare the energy released and reviewing their ideas after they have made their observations.

Practical notes

Remind the students that they need to predict before they do their experiment. You could then ask them to think about how they might decide whether a particular food has a lot of energy.

Students will need to clean the tin lid after each food is burned, and they may find it necessary to heat the food from above

Students will only need a small amount of each fuel (one peanut, about half a teaspoon of lard, margarine etc). Sugar would be another good example, but it is often difficult to light.



Remind students to wear safety goggles during the experiment, and make sure that the laboratory is well ventilated!

For the reporting-back session you could draw a table on the blackboard, listing foods and features of the burning which determine energy value. A student volunteer could then fill in the table as each group reports on its findings.

Students' response

Students tend to agree quite quickly that energy is involved in all of the activities, and that this energy comes from food. Arguments may arise about the 'sitting still' activities, and this leads into discussion of which activities require most energy. It also helps them focus on energy needed to maintain body processes.

The link between the energy we get from food and the energy released in burning may not be easy for some students; they may focus on more obvious aspects of the experiment such as ease of lighting, time of burn, colour of flame etc.

Instruction cards for physical activities 2

Sit still and
count to 100.

How many times can you
lift this weight from
floor to stool height
in one minute?

Sit and think for
half a minute.

How many press-ups can
you do in half a minute?

Run on the spot
for one minute.

How many star-jumps can you
do in half a minute?

How many step-ups can you
do in half a minute?

How many sit-ups can you
do in half a minute?

Energy in food

2

1. Find out how much energy different foods have by looking at the sides of food packets or tins. Record what you find out in the table below. Some examples have been written on to get you started; you can add other foods to the list.

NAME OF FOOD	ENERGY CONTENT kJ ENERGY PER 100g FOOD
Cornflakes	
Weetabix	
Rice Krispies	
Yoghurt	
Bread	

2. Try to bring in some empty (and clean!) packets or tins of food with energy shown on them for display.

Energy and ourselves

3

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
How much energy do we need?	Collect any food packets and read the energy values to the class.	Student volunteers enter values on poster.	poster of table from 'Energy in food' worksheet	
	A group of students at the front of the class perform different activities: sitting still, sitting and writing, running on the spot, squat thrusts, walking, as the rest of the class vote on which activities need most energy. (Act as chairperson.)			
	Summarise the consensus view and introduce the worksheet 'Food and energy' explaining how to relate energy needed from food to energy used.	Students complete worksheets working in groups. Representatives from some groups explain their answers to the class.	worksheets 'Food and energy'. (two per group)	
		In groups, students quickly decide where they think the energy of food comes from.	empty packets of cereals	
	Lead class discussion and summarise consensus view. At the end of the lesson you can burn a fossil fuel and ask students to think about where its energy comes from.		fuel sample apparatus for burning	

Homework suggestions: Researching formation of fossil fuels.
Students could be asked to draw bar chart showing length of time that different activities can be carried out after eating one bowl of cornflakes, and energy values of different foods, drawing on data in 'Food and Energy' worksheet.

The scheme in action : restructuring 3

Aims of the lesson

The activities in lesson three are designed to extend and reinforce the idea that energy can be quantified. Students also consider where the things we eat get their energy from.

Timings

Spend about 10 minutes on the physical activities demonstration. Students will need at least 20 minutes to discuss the worksheet questions and reach a group consensus. If you run out of time, move the fuel burning demonstration to lesson four.

Practical notes

You might like to give each student who is involved in the initial demonstration a single peanut, and ask 'how long can he/she run on the spot (for instance) to use up the energy supplied by that peanut?'

Give out one worksheet per pair of students, if possible, for ease of reading but ask them to reach a consensus within their groups of four.

Leaflets and other educational materials are available from Kelloggs. These explain where cornflakes get their energy from, and describe the process from sowing to breakfast bowl. Some input of materials such as these may help the group discusson work.

Also, many foods now have nutritional information printed on the label (bread, yoghurt, soft drinks, milk, cereal produce, baked beans). A number of useful computer programs may be obtained, e.g. 'Diet' (Cambridge University Press).

Students' response

Some students might find it difficult to relate burning foods to their personal energy requirements. Try asking 'what is the energy that food gives us?': you may find that students think that water and air are also sources of energy for us.

Some students may hold the view that plants get their food from the soil; the idea that plants synthesise food using energy from the sun is difficult for many students (15).

Food and energy

3

A. How far will you get on one bowl of cornflakes?

One large bowl of cornflakes supplies 500kJ of energy. This amount of energy will allow an average twelve year old to:

walk for 45 minutes

or run fairly slowly for 12 minutes

or cycle quite fast for 8 minutes

or sprint swim for 1 minute

or sit still for 2 hours

1. Which of these five activities uses up the bowl of cornflakes the fastest?

2. For which of these would a bowl of cornflakes last the longest?

3. How long would three bowls of cornflakes keep you alive if you were sitting still?

4. Anne said 'If I ate 60 bowls of cornflakes, I could swim for one hour.' Richard said she was being ridiculous. Can you give the two reasons that Richard was thinking of?

Food and energy (continued)

3

B. What are the energy values of different foods?

Each of the foods in the table supplies about 500kJ of energy.

Which food is the best source of energy?

Which food is the poorest source of energy?

Food	Amount to supply 500kJ of energy
cornflakes	1 large bowl
milk	pint
bread	1 large slice
butter	2 large pats
marmalade	2 tablespoons
bacon	1 medium rasher
eggs (boiled)	2 eggs
eggs (fried)	1 egg

Jane and David were trying to plan a breakfast for a day of hiking and climbing mountains. They have decided that they will need 2500kJ of energy to keep them going until lunch.

David says '500kJ goes into 2500kJ five times. All we need to do is to eat five times the amount of food. Easy - I'll have 10 boiled eggs.'
'Yuk!' says Jane 'I'm going to plan it better.'
Write down what you would choose to get 2500kJ of energy.

Energy and ourselves

4

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
Why is the sun's energy important?	Remind students about energy from fuels. You could either repeat the demonstration from lesson four with different fuels, or ask students to work in groups on the experiment. Follow this up by leading a class discussion of where fuels get their energy from, and the process of formation of fossil fuels.		Fuel samples, e.g. 3 in 1 oil coal paper wood peat apparatus for burning.	
	Introduce a circus of devices which convert and use energy from the sun. You could become part of the 'audience' here, giving you a chance to ask questions and promote discussion without making the student feel uneasy.	Students look at different devices, think about what the sun's energy is doing. Working in groups of four, students produce posters (one design per group) showing what can happen to energy from the sun. Each student is asked to produce a small sketched copy of his/her group's poster to put into books, when the main poster is finished. Representatives from groups explain their ideas to the rest of the class, using the poster to help their explanations.	Circus apparatus: piece of coal green plant radiometer solar panel photocell solar-powered calculator for each group: card, glue, scissors, coloured pencils.	

Homework suggestion: Students can be asked to complete their individual posters and stick them into their exercise books.

The scheme in action : restructuring 4

Aims of the lesson

The intention in lesson four is to extend the notion of energy from food to other ways of storing energy, particularly fossil fuels. It also emphasises the importance of energy from the sun, and provides a useful break point so that students can review their initial ideas (in lesson five).

Timings

Posters take time! Give them priority over looking at the circus of devices which use the sun as a direct source of energy.

Practical notes

Discussion in the first part of the lesson can focus on fossil fuels storing energy which originally comes from the sun, and the release of this energy when the fuels burn. Some of the fuel industries produce posters on the formation of fossil fuels; these might help to focus the discussion, if available.

If you feel you have the time, you could run the fuel burning as a group experiment, but you may then find that the poster production expands into the next lesson.

The circus of activities can act as a stimulus for the production of posters; its purpose is to demonstrate to the student that the sun is a source of energy for many different devices, which have many different uses.

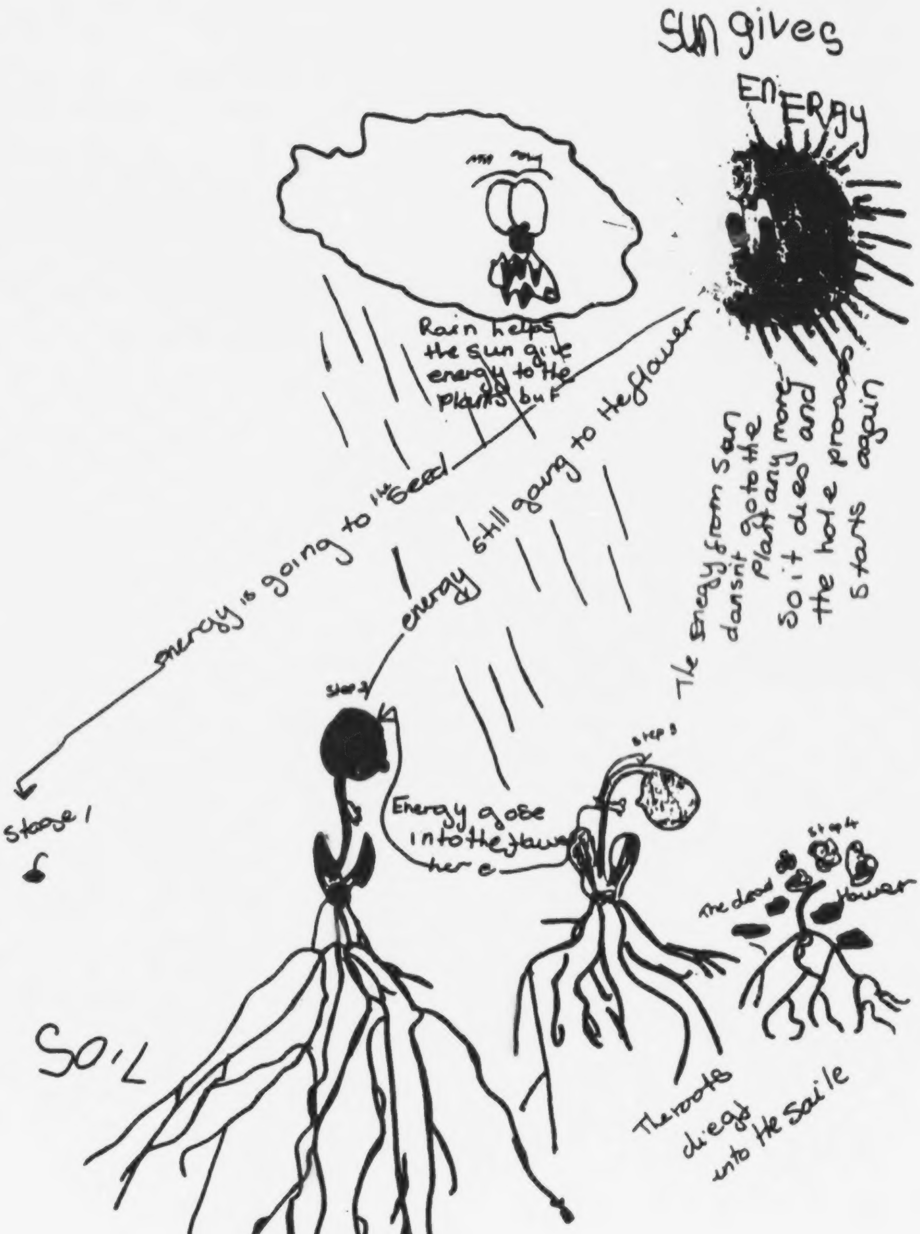
The posters could focus on one aspect of solar energy use (e.g. showing the transfer of energy from the sun to plant life to animal life ... etc.). Alternatively, some groups could illustrate a variety of possible transformations, focussing on devices they have seen in the circus and on other devices they might know about at home. Some students may be able to use the activity as an imaginative exercise, trying to 'invent' a device to use the sun's energy to do something useful.

You could introduce the notion of conservation of energy at this stage, by asking students to consider whether all of the energy is transferred each time.

Students' response

Typically, students seem to know that energy from the sun is needed for plant growth, but the mechanisms involved are not understood. The ideas used by students in this activity were similar to those encountered in a similar activity in the CLISP scheme on Plant Nutrition (16).

An example of one 11 year old student's poster design is shown below.


Sun gives ENERGY
Rain helps the sun give energy to the plants but
energy is going to the seed
energy still going to the flower
The Energy from Sun dansit go to the plant any more so it dies and the hole proces starts again
stage 1
step 2
Energy gose into the flower here
step 3
step 4
The dead flower
SOIL
The roots diegs into the saile

Energy and ourselves

5

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
How are the sun, food and me connected?	Recall and review the consensus view from the previous block of lessons. (The ideas should come from the class, if possible.)	Students make short notes on the consensus view, then review their ideas, lists and categories (from lesson one), changing their categorisation of ideas if necessary.	for each group: posters of ideas from lesson one. additional statements: for students to classify	
	Hand out prepared statements for students to sort in groups and add to their 'ideas posters'.			
In what other ways can we store energy?		In groups of four, students 'brainstorm' on other ways of storing energy. Then each group thinks about four activities (of eight) answering worksheet questions about the energy involved, working in pairs.	worksheet: 'How can we store, and use energy?' (one per pair) circus equipment: catapult syringe/balloon plank seesaw large manometer spring sponge, etc. instruction cards for the activities.	
	Ask students to keep thinking about the activities for next lesson - representatives from groups will be asked to report back then.			

Homework suggestions: Students could be asked to think about other ways of storing energy around their homes, or to think about other activities and add them to the worksheet.

You could ask students to consider the forces involved in the activities, and to think about why the force might be different from energy.

The scheme in action : review

5

Aims of the lesson

The intention in this lesson is to give students an opportunity to review any change in their ideas from lesson one, then to change the focus of the topic from 'where does our energy come from?' to 'how can we store energy?'.

Timings

At least half of the lesson should be spent on students reviewing the posters of statements from lesson one, and making notes (briefly) in their books if you feel that it is necessary.

Practical notes

You may like to give out a list of statements about energy (see example sheet) for students to discuss in groups. Alternatively, you could ask students to write new statements, or to try to explain what they mean by energy.

Students should be asked to work through the circus of activities in pairs, rejoining as groups of four next lesson. Ask them to keep the description of what they did very brief (even restricting it to the title of the activity).

'What has happened to the energy?' can form the focus of class discussion in lesson six, so it will be helpful if you can find out what kinds of ideas students are using at this stage.

Students' response

Some ideas about energy produced by eleven year old students are shown overleaf. These students still focus on human energy, but ideas about energy in food and fuel are more dominant than in lesson one.

Energy comes from the Sun to make our food and Crops grow. We eat the food and Crops like Sweet Corn and other thing, and We eat the energy. Then it goes round our body and gives us energy

We think energy is power and heat. Energy is sometimes invisable and sometimes visable, for example you can't see gas but you can see the sun. Almost everything has energy

I think energy is in all op us It Keeps us all alive Energy is also dipperent kinds op power for example gas and electricity. The energy in your body can run out like when you are running and you have to stop because your energy has run out and you are tired but you always get your energy back. The Sun gives out energy which is heated

I think energy is all to do with heat. Energy is Visable Sometimes Eg Gas, Coal, fire these are visable and let off energy

When students are answering questions about the physical activities, most will say that the energy came from food, their arm/leg/hand or muscles, and that they used energy in the activity. However, some may think that only living things or only moving objects have energy, and this may be reflected in their answers to 'what happened to the energy?' and 'was the energy stored?'.

Most students tend to think that, at the end, energy has 'gone' or has been 'used up', but a few may suggest that it has gone 'into the air'.

Examples of additional statements for students to classify

5

Fridges take energy from food.

Plants get their energy from the soil.

We sleep to get our energy back.

Machines use up energy.

Pulling and pushing are examples of energy.

When you lift something up you give it energy.

Energy is an invisible substance.

Without the sun we would have no energy.

Sometimes you can run out of energy.

Only living things can ever have energy.

Instruction cards for activities

5

See-saw

Put a set of weights on one end of the see-saw.

Put another set of weights on the other end.

Take off the second set of weights.

Sponge

Twist the sponge as hard as you can.

Let go.

Strength

Push the coils of wire together.

Let go.

Breathalyser

Blow as hard as you can down the tube.

Catapult

Pull back the rubber band with the paper pellet in.

Let go.

Spring

Hang a weight on the end of the spring.

Take off the weight.

Witchcraft

Sit on the broomstick and go for a ride!

Balloon and syringe

Push the syringe in the then release it.

Pull the plunger back to the zero mark.

How can we store and use energy?

5

Some activities have been set up for you around the laboratory. Follow the instructions on the cards and answer these questions for each activity:

1. What did you do?

2. Where did the energy come from?

3. What happened to the energy?

4. Was the energy stored? If so, where?

5. Where was the energy at the end?

Make sure that you agree your answers with your partner. When you have worked through a few of these activities, you will be asked to join up with the other half of your group to discuss your ideas.

One member of your group will be asked to tell the rest of the class about your ideas. Choose someone to do this and make sure that he or she knows what you have agreed.

Energy and ourselves

6

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
How do we store and use energy?	Act as chairperson, summarising students' ideas and drawing out any consensus.	Students continue the experiments from lesson five (in pairs) for a few minutes. Then, in groups of four, students review the activities. A representative from each group reports back on one of the activities.	'Energy circus' from lesson five	
	Raise a large weight on a pulley, by pulling on a forcemeter attached to the rope. Ask the class 'Whatis different - what changes as the weight is lifted?' Lead a class discussion focussing on the difference between force and energy as it relates to the pulley demonstration.		means of lifting large weight e.g. pulley rope, weight (e.g. 5-10 kg sandbag) dial type forcemeters	
	As before, act as chairperson, summarising ideas.	In groups of four, students discuss the force/energy distinction in relation to the circus of activities from the last lesson. Representatives from some of the groups report their ideas to the class as a whole.	worksheet: 'Energy and force' (one per pair)	
	At the end of the lesson, hoist the weight to the ceiling and tie it there, posing the question - 'Has the energy changed?'			

Homework suggestion: Students could be asked to review their posters of statements about energy, to consider whether forces are involved in any of the sentences, and whether force and energy usually go together.

The scheme in action : restructuring 6

Aims of the lesson

This lesson is intended to extend students' ideas about stored energy and to help them to make a disinction between energy and force.

Timings

Spend about 30 minutes on reviewing the activities of the previous lesson and reporting back from the groups.

Practical notes

Try to find a weight sufficiently heavy that students can readily accept that they must use energy to lift it (5-10kg).

At the end of the lesson, leave the weight suspended from the ceiling and ask students to think about whether energy is involved, and what will happen to it between now and next lesson.

N.B. In scientific terms, the energy is not, of course, stored in the weight, but is stored in the weight-earth system (hence gravitational potential energy). You may wish to avoid talking about energy 'in the weight' for this reason. However, the aim of this activity is to move students towards acceptance that energy can be associated with inanimate objects, and too much emphasis on the exact location of the energy may not be helpful at this stage. (Some students may suggest that energy is in the rope rather than the weight, and you could raise this as an interesting issue for discussion.)

Students' response

It is likely that the reporting back on lesson five, and the subsequent discussion will lead to students recognising that energy can be stored in elastic systems (balloons, catapults etc.). However, they may experience difficulty with the idea of gravitational potential energy.

Students tend to think of forces as pushes or pulls which cause movement; they may not identify weight as a force.

Students may also think that the force changes as the heavy object is lifted, i.e. that it weighs more when it is higher up. They may not accept that energy has been transferred to the weight (system) when the weight has been lifted since it is not moving, and it is not (and has never been) alive. However, they will probably accept that energy is 'used up' in lifting it, i.e. that they lose energy. Do not expect closure at this stage. The point is considered again in the next lesson.

The distinction between force and energy may not be clear for some students at this stage, as is shown in one student's answers to the worksheet questions:

A. Think about the pulley you have just seen.

1. Where was the force?

   We ~~tha~~ think the Energy was in the force we made to pull it.

2. Did the force change as the weight was lifted?

   The force of the weight changed as we pulled it.

3. Did the energy change as the weight was lifted?
   If so, how did it change?

   The energy changed because the weight seemed to get lighter and not as much energy was been used.

4. Where did the energy come from?

The energy came from our bodies and ~~Ea~~ the musals that had been Strongend by the food We eat.

5. Where did the energy go to?

The energy went to the strenth and into our musals to able us the pull the weight.

Syringe activity

Where was the force?

The force was in the way we used the Syringe ~~in the air~~. the air was in the Syringe

Did the force change? How do you think it changed?

The force did change because when we take out the air the ballon went down

Was the force the same as the energy?

The force most have been the Same as the energy because we need them both to do heavy work.

Energy and force

6

A. Think about the pulley you have just seen.

1. Where was the force?
2. Did the force change as the weight was lifted?
3. Did the energy change as the weight was lifted?
   If so, how did it change?
4. Where did the energy come from?
5. Where did the energy go to?

Energy and force (continued)

B. Think about the things you did in your last lesson. Which of them involve forces? Choose one of the activities which did involve forces, and answer the following questions.

6. Where was the force?

7. Did the force change? If so, how did you think it changed?

8. Was the force the same as the energy?

Energy and ourselves

7

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
Do lifted objects have energy?	Briefly review the ideas encountered during the previous lesson. Then ask whether lifting the weight has stored energy, and if it has, how can we measure it? (Dropping a weight into something which deforms e.g. a cardboard box, can help!)		Pulley and weight system (or some means of lifting and supporting a large weight).	
What does the energy of lifted objects depend on?	Lead a class discussion focussing on ways to find out how the energy stored when objects are lifted changes with the height raised and the mass of the objects.			
	Summarise and guide discussion.	Working in pairs, students compare the effects of dropping objects of the same shape and volume but different mass into sand from different heights. Students complete worksheet. Pairs recombine to form fours, discuss results, reach consensus and discuss second worksheet. Representatives from some of the groups report back on their ideas to the rest of the class.	for each pair: ball bearings, marbles, trays, sand, rulers, spring balances, polythene bags. worksheets: 'Comparing stored energy' and 'Energy weight and height'.	

Homework suggestion: Students could be asked to think about, and find examples of ways of making lifting easier.

The scheme in action : restructuring

7

Aims of the lesson

This lesson builds on lesson six, reinforcing the idea that lifting objects increases their energy, and goes on to introduce the factors which influence the amount of energy stored (mass and height raised).

Timings

Most of the lesson is intended to be spent on students' practical work, but you will need to allow about 15-20 minutes for the reporting back session at the end.

Practical notes

You could ask students to design the experiment in groups, but this will probably require more time (two lessons might be needed). In discussing experimental design, you could review the idea that the weight does not change with height. Here you could return to the pulley system, attaching a spring balance to one end of the rope and the weight to the other. Ask the pupils to read the spring balance when the weight is down and again when it is lifted up.

Ball bearings and marbles the same size may be difficult to find, but any objects of the same size and different weights will suffice.

The marbles and ball bearings can be weighed by putting them in the polythene bag and attaching the bag to the newton meter.

Take care in selecting newton meters. They need to be sensitive enough to distinguish between marble and ball bearing.

Students' response

Some discussion may still be necessary to convince students that lifting the weight is a way of storing energy, and the idea that weight stays constant is very difficult for students to accept, as is illustrated here (from 'Comparing Stored Energy' worksheet):

1. What happens to the weight of an object when you lift it higher?

When you lift the weight of an object the weight get's heathier. And if you lift it higher, above your head It get's much more heathier.

2. What happens to the energy of an object when you lift if higher?

When you lift an object higher the energy start's forcing preasure on the weight

3. How can you tell?

You can tell that the forcing preasure on the weight because it get heathier.

Comparing stored energy

7

Talk about these questions in pairs. When you agree about your answer write it down.

Comparing energy at different heights

1. What do you think will happen to the weight of an object when you lift if higher?

2. What do you think will happen to the energy of an object when you lift it higher?

Drop the marble into the sand tray from 50cm above the bench.

Now drop the marble into the sand tray from 100cm above the bench. So that it makes a dent near to the first one.

3. Is the dent smaller, bigger or the same size as it was before?

4. What does this tell you about the energy?

Comparing stored energy (continued)

7

Comparing weights at different heights

Weigh the marble near the floor. Write down the weight in newtons. Now weigh the marble just above the bench. Compare the weight with the reading you have just taken.

5. What does this tell you about the weight of the marble?

Comparing energy for different weights

Weigh the metal ball bearing. Write down the weight in newtons.

6. Does it weigh more, less or the same as the marble?

7. How much energy do you think it has, when it is 100cm above the bench?
   - more than the marble had when it was 100cm above the bench
   - less than the marble had when it was 100cm above the bench
   - the same as the marble had when it was 100cm above the bench

8. Why do you think that?

Now drop the ball bearing into the smooth sand from 100cm.

9. How big is the dent?
   - the same size as the marble made from 100cm
   - bigger than the marble made from 100cm
   - smaller than the marble made from 100cm

10. What does this tell you about the energy?

Energy, weight and height

7

Talk about these questions in your groups of four. When you agree about your answer, write it down.

1. What happens to the weight of an object when you lift it higher?

2. What happens to the energy of an object when you lift it higher?

3. How can you tell?

4. Does a heavy object have more, less, or the same amount of energy as a lighter object at the same height?

5. How can you tell?

6. Where does the energy come from when you lift an object?

7. Where does the energy go to when the object falls and hits the ground?

Energy and ourselves

8

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What happens to our energy when we are lifted?	Review the activities and ideas encountered in lessons six and seven, and ask what happens when people are lifted by a lifting device.			
	Lead a class discussion, focussing on a demonstration in which one student is lifted to bench height using a rope and pulley system. Has the person's energy increased? Where has the extra come from? Ask students to suggest what might be different if they lift themselves to the bench top; and what might affect the energy they use to do so. Also encourage students to discuss how they might test their ideas.		heavy lifting pulley system	
		Working in groups of four, students test their ideas; one member of each group checks his or her weight on the floor, on a small stool, on a large stool and on the bench. Students then observe the effectings of jumping from various heights onto a seesaw system, discuss their results and draw conclusions about the energy used.	bathroom scales for each group; dowel (or pencil) wooden planks various stools worksheet: 'Energy and Ourselves'.	
	Lead a class discussion, focussing on how much energy each student has (comparatively) at different heights, and on where the energy goes when the students jump to the floor. Representatives from some groups report back to the class.			

The scheme in action : restructuring 8

Aims of the lesson

This lesson extends students' ideas about stored energy in lifted objects into a difficult area - what happens to our energy when we are lifted? Students are asked to consider the distinction between being lifted by external means and raising one's own weight.

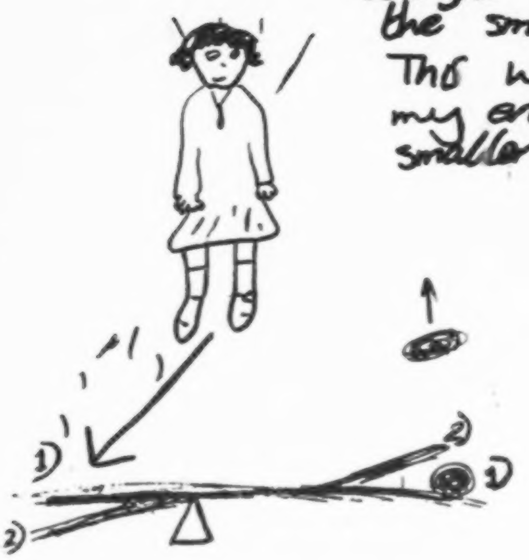
Timings

Spend about half of the lesson on students testing their ideas in group practical work and discussion.

Practical notes

The 'testing ideas' activity should be set up as described by one student:

We got a weight and a long peace of wood we thon put the weight on one end I Jumped on the end that had No weight on. The weight of my energy made the smaller weight Jump. This was because I forced my energy to lift up the smaller weight.



Students' response

Students may not recognise initially that they raise their own weight, i.e. exert a force, when climbing.

Raising a student on a pulley system is an attention-grabber!

lee. was on the harness and a few people were trying to pull him up. we were forceing lee up.on the frame. we then tied the rope on the harness. so lee was hung on the Harness. our energy pulled lee up It took a teacher and half the class to pull lee up becouse he is big.

we the Lowered him down he did not come down with a crash so he was lugy. our energy got used up, where lee's was still inside him, because lee had not wasted any energy at all

When asked to decide what makes a difference to the energy gain, students might suggest factors such as height, weight, speed of climb etc.

Students tend to agree quite readily that we have more energy the higher we climb, based on the height to which the object on the seesaw is raised.

How high did you climb?

3cm

What happened to the weight?

The weight didn't come off the plank very high

How high did you climb?

Stool

What happened to the weight?

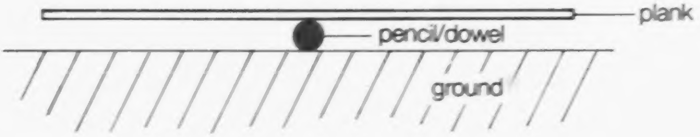
The weight come off the plank very high

You could introduce the idea of rate of energy transfer - i.e. 'how is energy affected by how quickly you climb?' Students may confuse rate of energy transfer with total energy transfer, since energy used in climbing stairs is affected by rate of climb (due to human physiology, heat generation etc.) although potential energy is not.

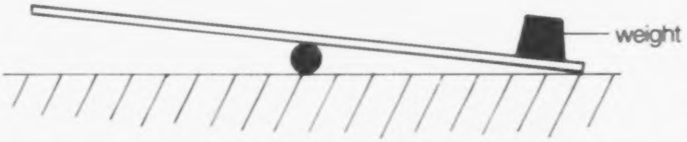
Energy and ourselves

8

Balance the plank on the piece of pencil or dowel, like this:



Put a weight on one end of it, like this:



then jump onto the other end, and watch what happens to the weight.

Try jumping from different heights (not higher than the bench top!) and see what happens when different people jump onto the plank.

Now answer the questions on the other side of this sheet.
Talk about the questions in your group. When you agree about your answer, write it down.

Energy and ourselves (continued)

8

1. Where did the energy come from when you did the climbing yourself?

2. Which person in your group had most energy at each height?

3. Why did this person have most energy - how could you show it?

4. Would you have more, less or the same energy when you climbed onto the bench, compared with being lifted onto the bench?
   Give reasons for your answer.

5. Where did the energy go when you jumped from the bench to the floor?

Energy and ourselves

9

10

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What have we learned about energy?		Students review their posters of statements about energy. 'Agree' and 'disagree' statements are re-sorted and new statements added where required.	statements posters from lesson one	
		In groups of four, students discuss recent questions relating to energy acquired when climbing depends on, and where it comes from. Representatives from the groups report back to the class as a whole.		
	Lead the discussion and help students to produce a consensus view; students make notes briefly.			
	Introduce the end-of-topic activity - to design and build a device which stores energy, then releases it to do something useful.	Working in groups, students design, build and test their devices. Representatives from each group report on their designs, referring to the device and to posters produced during construction if necessary.	e.g. balloons, springs, syringes, cotton reels, elastic bands, candle pieces, etc.	
	Lead discussion and award marks for application of ideas about energy and successful design.			

The scheme in action: application and review

9/10

Aims of the lessons

The final lessons of the scheme are an opportunity to review their initial ideas about energy and to apply new ideas in an unfamiliar context.

Timings

Try to keep note-taking to a minimum in lesson nine, and leave about half of the lesson for students to make a start on their design work.

Spend about two thirds of lesson ten on completing the construction and testing, and about 20 minutes on groups describing their designs to the class.

Practical notes

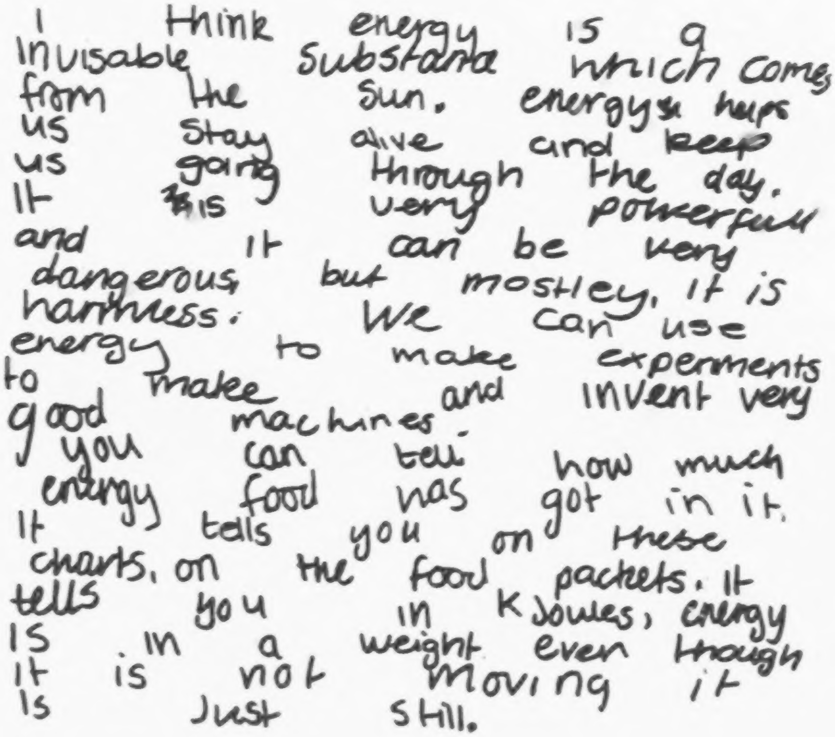
When students re-sort their statements from lesson one, they may still find that there are some that they are not sure about. Use this to reinforce the notion that their ideas are changing all the time, and that although they might have 'finished' this topic; they still have something to learn about energy. As in lesson five, you could ask students to write a few sentences about energy.

For the design activity, you could simply provide a range of materials and give students a relatively free hand. Alternatively you may wish to have a selection of design plans available (two examples are included here). You could extend this activity to two or three lessons, even liaising with the CDT department to allow more elaborate designs to be constructed.

It is helpful to motivate students by setting up the activity as a competition, with a small prize for the best design and exposition.

Students' response

Students' writing about energy in at the end of the topic illustrates the change in their ideas.



I think energy is a
invisable substance which comes
from the sun. energy helps
us stay alive and keep
us going through the day.
It is very powerfull
and it can be very
dangerous, but mostley, it is
harmless. We can use
energy to make experments
to make and invent very
good machines.
you can tell how much
energy food has got in it.
It tells you on these
charts, on the food packets. It
tells you in KJoules, energy
is in a weight even though
it is not moving it
is just still.

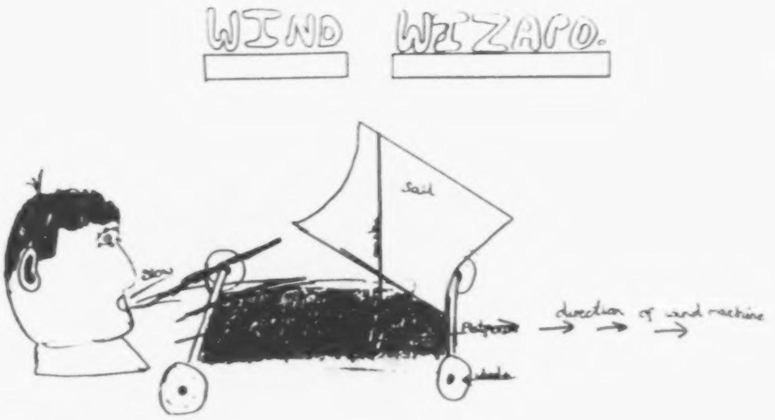
'I think energy is a invisable substance which comes from the sun. energy helps us stay alive and keep us going through the day. It is very powerfull and it can be very dangerous, but mostley, it is harmless. We can use energy to make experiments to make and invent very good machines. you can tell how much energy food has got in it. It tells you on these charts, on the food packets. It tells you in KJoules, energy is in a weight even though it is not moving it is just still.'

I think energy is something that keeps everybody alive We get it first from the sun and also the food which we eat. The food helps us run, walk and move about. The energy is used in lots of different ways.

Energy keeps humans and animals alive. The energy in machines helps them to work and do different things like moving (cars).

We can use energy up when we run for a long time or dancing. When we have used up the energy we will get more if we eat or drink or if we just have a rest. Everybody and about everything needs energy in some way.

The following design for a device to illustrate energy was produced by one group of twelve year olds. Their focus was on wind energy.



The wind has energy because in a gale force wind it can blow trees and houses away and make big waves come over the coast at blackpool and over sea side towns

Making a balloon rocket

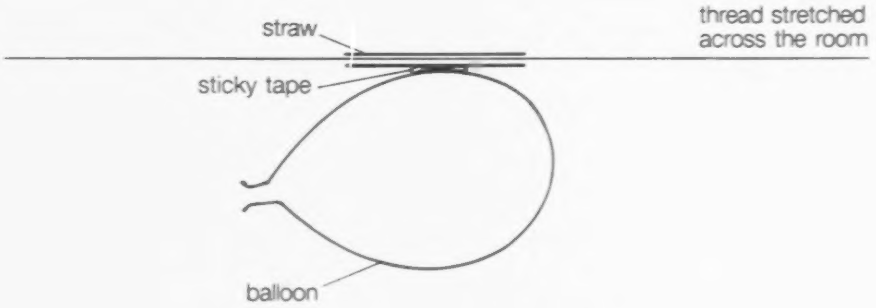
9

10

You will need - a long piece of cotton thread
(long enough to stretch across the room)
drinking straws
balloons
sticky tape

What to do

Try to make a balloon-powered 'jet-engine' cross the room on a thread.


straw
thread stretched across the room
sticky tape
balloon

You will need to get the sticky tape to stick to the balloon without
bursting it!

AND

You need to make sure that the balloon moves smoothly along the thread.

Making a toy tractor

9

10

You will need - cotton bobbin
elastic band
short piece of candle
1 whole matchstick
1 half matchstick

What to do

Use the materials to make a 'toy-tractor'. The elastic band must be wound up and when released cause the tractor to move.

Energy and ourselves

or, fuller instructions:

Making a toy tractor

9

10

You will need - cotton bobbin
elastic band
short piece of candle
1 whole matchstick
1 half matchstick

1. Place half matchstick through one end of the rubber band.
2. Thread the rubber band through the centre of the bobbin so that the matchstick holds it.
3. Thread the free end of the rubber band through the candle (wick removed).
4. Push the whole matchstick through this end of the rubber band.
5. Using the whole matchstick wind up the rubber band and then release.

Energy and ourselves

Materials reference list

LESSON ONE:
- for each student:
  - 5 strips of paper (approx. 3cm x 10 cm) per student
- for each group:
  - poster paper to serve as mount
  - glue
  - wall space
  - coloured pens or stickers

- OHP transparency with instructions

LESSON TWO:
- instruction cards

- for each group:
  - food samples (lard, margarine, cornflakes, dry bread, dried fruit, nuts etc.)
  - tongs
  - balance
  - tin lids
  - heat resistant mats
  - spoons
  - spatulas
  - food packets

homework: worksheet: 'Energy in Food'

LESSON THREE:
- for each group:
  - poster paper
  - worksheets: 'Food and Energy' (two per group)
  - empty cereals packets
  - fossil fuel sample
  - apparatus for burning demonstration

LESSON FOUR:
- fuel samples
- apparatus for burning demonstration
- piece of coal
- green plant

selection from:
- radiometer
- solar heating panel
- solar-powered calculator
- photocell
- cards describing devices

- for each group:
  - card
  - glue
  - scissors
  - coloured pencils
  - magazine cuttings

Materials reference list (continued)

LESSON FIVE:	worksheet: 'How can we store and use energy' (one per pair) catapult syringe balloon plank seesaw
selection from:	large manometer springs (large and small) sponge broomstick weights instruction cards for activities
from lesson one:	posters of ideas additional statements for students to classify
LESSON SIX:	large pulley or method of lifting large weight 5-10kg sandbag rope dial-type forcemeters worksheet: 'Energy and force' (two per group)
from lesson five:	energy circus devices
LESSON SEVEN:	for each pair: ball bearings, marbles or similar small objects of same shape and size, different mass trays sand meter rules spring balances worksheets: 'Comparing Stored Energy', 'Energy, weight and height'
from lesson six:	pulley and weight system
LESSON EIGHT:	heavy lifting pulley system bathroom scales for each group: 500g weights wooden planks various stools pencil or 1 cm dowel (one piece per group) worksheet: 'Energy and Ourselves'
LESSONS NINE AND TEN:	equipment for experimental design for each group; e.g. balloons, syringes, elastic bands, springs, cotton reels, candle pieces etc.
optional:	instruction sheets
from lesson one:	posters of ideas

Energy for the consumer

Energy for the consumer

1

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What do we use fuels for?	Introduce the lesson by showing slides of fuels being used for cooking, heating transport etc., in a rural African community.		slides, projector, photographs, etc.	
	Class discussion, contrasting lifestyle of African family with that of students, in terms of fuel requirements, fuel gathering and use etc.		for each group: worksheet: 'What makes a good fuel?' suggested fuels: coal wood peat charcoal coke goggles bunsen burners tripod gauze taper tin lids	
Do fuels have different 'values'?	You can also demonstrate other fuels burning (fuels which may be unsuitable for students to use, such as paraffin, alcohol, petrol, diesel, etc.). Construct a composite table on the blackboard and suggest differences between students' ideas and those of similar children in the African community. Then distribute tables of energy values and costs of fuels, and explain their meaning.	Students carry out experiment, comparing the properties of different fuels, following a worksheet. Students work in groups, discussing questions as they work on the experiment. Representatives from the groups report back to the class as a whole on their observations.	optional (for demonstration): paraffin petrol diesel alcohol	

Homework suggestions: Questions about fuels, energy values, cost ('Choosing fuels' worksheet). Students could be asked to collect materials for next lesson's collage (newspaper and magazine advertisements and articles).

The scheme in action : orientation

1

Aims of the lesson

The intention in lesson one is to orientate students to a study of energy in domestic contexts. Using slides of fuels used in a community setting different from their own helps focus attention on what they may otherwise take for granted.

The practical work involved (burning fuels) is likely to be familiar to some students, and this familiarity may offset the introduction of reporting back as a class activity, which they may initially find novel. This lesson is also the first in which students are asked to work in the groups which will be maintained throughout the topic.

The most widely used fuel in students' direct experience is likely to be gas, because it is the most commonly available. Another purpose for the lesson is to introduce the idea that usefulness, convenience, availability and cost of fuel are prime concerns and depend on the culture and environment in which we live.

Timings

At least half of the lesson should be devoted to students' experimental work and reporting back. If the second worksheet 'choosing fuels' is to be used as homework, it could be started during the last few minutes of the lesson. Alternatively, you could lead a class discussion focussing on the worksheet questions.

Practical notes

Group folders, if they are to be used as a means to store written work, should be distributed during this lesson.

The worksheet 'what makes a good fuel?' should be worked on as a group, but the second 'choosing fuel' (plus 'energy values and cost') can be used for an individual activity.

Reminder: prepare fuels beforehand!
When the fuels are distributed, ensure that small quantities are used, and ask students to expose the fuel to the bunsen burner flame (heating from above) for the minimum amount of time to ignite it. We suggest that three fuels per group, plus gas (bunsen burner) is adequate. Avoid powdered fuels, as they can prove difficult to burn in these circumstances.

If you draw a table on the board, or poster, for the report back session, a student can be asked to fill in the ticks and crosses thus:

	Gas	Coal	Peat	Coke ....
lighting?				
smoking?				
heat?				
good fuel?				

If you decide that you would like students to produce some display work, ask them to start collecting material now.

Students' response

Typically students respond well to the slide presentation if it is personalised, i.e. 'imagine what it would be like if....'.

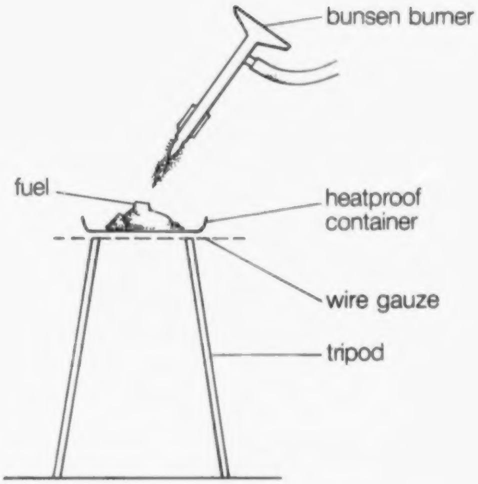
Most students find coal and coke difficult to burn, and thus rate them as poor fuels, preferring, for example, wood. There may be some disagreement about observation (e.g. the 'hotness') and interpretation of what makes a good fuel. These issues can stimulate class discussion.

What makes a good fuel?

1

MAKE SURE THAT YOU ARE WEARING GOGGLES WHILST YOU BURN THE FUELS

WHAT YOU SHOULD DO:



1. BURNING FUEL

   Set up the apparatus as shown, and place a small amount of fuel on the heat-resistant paper. Heat the fuel strongly from above until it lights, then turn the bunsen burner off and watch the fuel burning.

2. QUESTIONS

   Answer the questions as fully as possible, for each fuel you burned. Put your answers in the form of a table like this in your books:

	Fuel 1	Fuel 2	Fuel 3	Fuel 4
How easily did it light?				
Did it give off smoke?				
Did it seem to give out much heat?				
Is this a good fuel?				

Choosing fuel

1

TABLE A: ENERGY VALUES OF DIFFERENT FUELS

One kettleful of water needs about half a megajoule of energy to make it boil. One megajoule = 1,000,000 joules.

Fuel	Energy value (megajoules per kg)
Coal	35
Wood	16
Peat	16
Charcoal	34
Coke	29
Paraffin	46
Alcohol	29
Petrol	47
Diesel	45
Natural Gas	43 (the mass of $\frac{1}{2}m^3$ is about 1kg)

TABLE B: COMPARATIVE COSTS OF DIFFERENT FUELS

10MJ of energy is just enough for one good hot bath!

Fuel	Cost in Leeds for 10MJ of energy (typical daily wage 2000p)	Cost in Kakamega, an African village, for 10MJ of energy (typical daily wage 130p)
Coal	4p	Not available
Wood (bundled)	15p	Free
Peat	16p	Free where available
Charcoal	12p	2p
Coke	4p	Not available
Paraffin	18p	5p
Alcohol (Meths)	60p	Not available
Petrol	11p	11p
Diesel	10p	8p
Natural Gas	3p	Not available
Electricity	15p	Not readily available

Choosing fuel (continued)

1

Use tables A and B as well as your lesson notes to answer the following questions:

1. Which of these fuels have you ever seen used in your home?

2. Which of these fuels are used locally?

3. Are there any purposes for which solid fuels are better than liquid fuels?

   Are there any purposes for which liquid fuels are better than solid fuels?

4. Why are gas and electricity by far the most used fuels in Britain? Why are they not used in an African village?

5. What makes wood more useful for cooking in an African village than where you live?
   (There are at least five reasons.)

6. Which fuel has the highest energy value? Why isn't this fuel more widely used in our homes?

Energy for the consumer

2

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
Where does the energy in our homes come from?	Introduce the lesson by explaining the focus of work for the next few weeks, and demonstrating use of energy in several common domestic devices.		Domestic devices: kettle (boiling a cup of water) drill (making a hole in wood) whisk (in bowl with liquid) hairdryer curling tongs 40W bulb 100W bulb	
In what ways do we use energy in our homes?		Students complete worksheet questions focussing on these appliances, in groups of 4. Groups are then asked to produce a poster about some of the devices and to add other devices which are commonly used in their homes.	for each group: worksheet: 'Using electrical energy' poster paper pens	
		Magazine cuttings could be used to illustrate energy devices.		
	Act as chairperson, summarising the ideas arising from the students.	Representatives from each group report on the posters to the class.	storage space display space	

Homework suggestion: Students could be asked to write an essay about energy in their homes (e.g. 'Imagine living in a house without electrical energy.').

The scheme in action : eliciting ideas 2

Aims of the lesson

The purpose of the lesson is to elicit students' ideas about energy in their homes, specifically where energy comes from, what happens to it and where it goes to. It also introduces the idea that energy may be used at different rates by different devices.

If there is time, you could also begin the collage in this lesson, providing a means to illustrate how students' ideas have changed during the topic, and helping them to link their lessons to everyday experience.

Timings

About half of the lesson could be allocated to students talking in groups about the devices and producing posters. The remainder of the lesson should be used for groups to report on their ideas to the class.

Practical notes

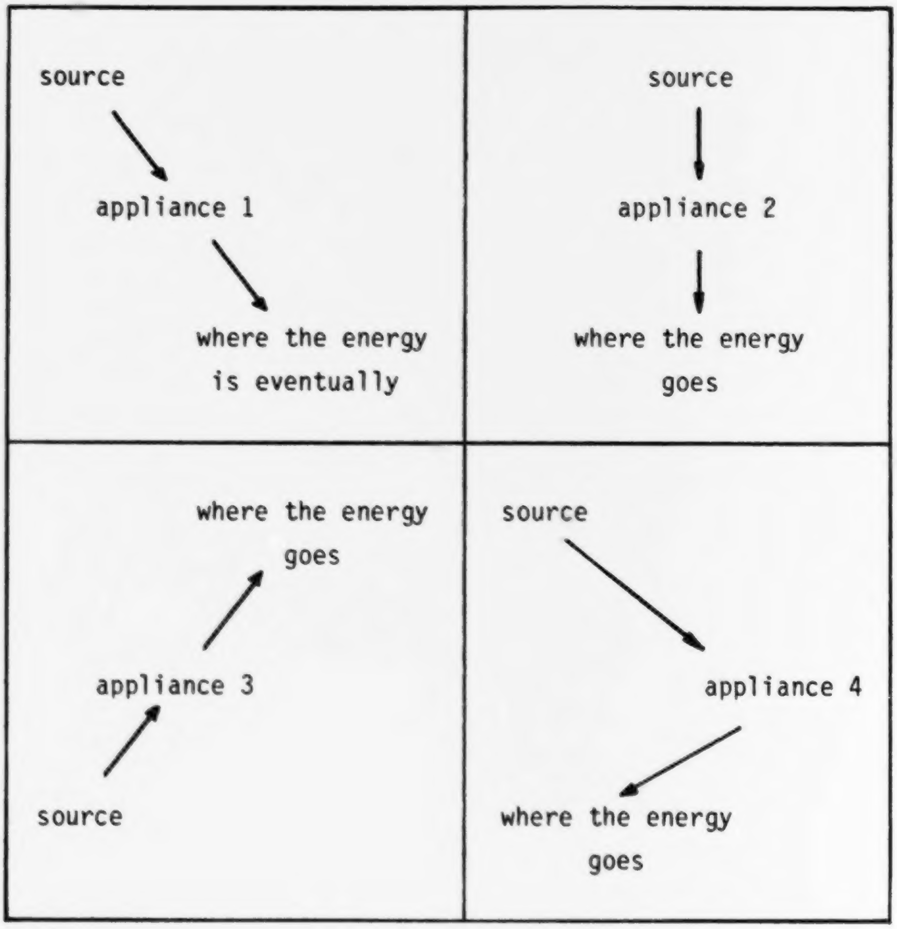
As you introduce the activity, you might like to use a fairly 'spectacular' device, e.g. an electric drill drilling a hole in a piece of wood, to explain what you want the class to do.

When 'real' devices are used by students in lessons, be particularly aware of safety.

Try to avoid using all kitchen devices, and make sure that the girls do not end up with the food mixer!

It helps if the domestic devices chosen reflect a variety of sources of energy (AC and DC electricity, oil, gas, candle wax, calor gas, etc), and if some of the electrical devices are carried forward to lesson three, for metering. We suggest that each group considers two or three devices (at least one of which should not use mains electricity), then draw on their ideas about other appliances in their homes to produce a poster.

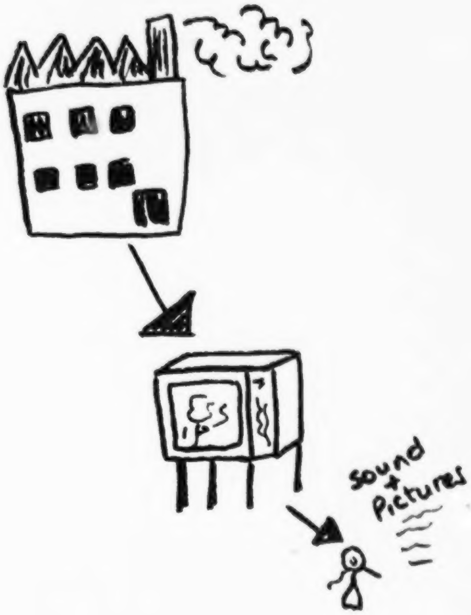
A possible format you could suggest to the students is:

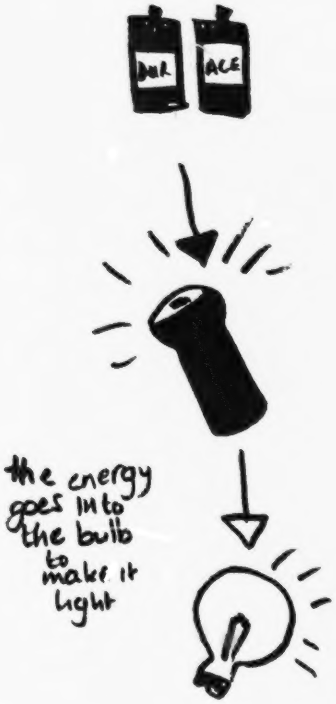

source
appliance 1
where the energy is eventually
source
appliance 2
where the energy goes
where the energy goes
appliance 3
source
source
appliance 4
where the energy goes

A suggestion for collage work: use extra thickness wallpaper lining paper, two to three metres length per group. The posters produced in this lesson can be fixed to one end of the paper as a beginning to the collage. If there is insufficient room in the laboratory to put all the collages on the wall, try using the corridor outside.

Students' response

Many groups may think that the energy is simply 'used up' or 'just goes'. We would suggest that you avoid formal introduction of the notion of conservation of energy at this stage; simply asking where the energy has gone will stimulate discussion. Most groups recognise that electrical devices get their energy from power stations, but some unexpected ideas may occur, e.g. television energy comes from the B.B.C. The energy outputs identified tend to be limited to what we want out of the device. For example:




DUR
ACE
the energy goes into the bulb to make it light

The homework activity gives the students a chance to use their imagination, and most seem to enjoy the opportunity. An example of one student's work is shown overleaf.

A Day Without Electricity

I awoke ~~at~~ ~~10.00am~~ to find my electric alarm clock had gone off. I went into the bathroom to find no hot water, because our water pump is electric. I decided to get a cold wash to save time. I quickly got dressed and went downstairs to get my breakfast. Luckily we had a gas cooker so I had a slice of toast. After breakfast I left the house and went to catch the bus. When I arrived at school it looked so dark. Suddenly I remembered no electricity so no lights. I received my late mark then went to my lesson. The classroom looked so dark it was hard to see when far from the window. Next lesson was science but we couldn't do any practical because we were useing electrical appliances. After Science everything was as usual except for the lights. When I arrived home it was getting quite dark. At home we had to use candles for light with no televiseon it was quite boreing, after tea there was the problem of the washing up, because of no hot water we had to boil hot water in a pan then, pour it into the sink. Dureing the evening we all sat round the table with about eight candles playing cards. At about 10.00 we all decided to retire agreeing it had been a long day. We all went upstairs carrying our candles. As I lay in bed I looked forward to the day ahead WITH ELECTRICITY.

Using energy

2

In your group, discuss the questions below, and decide on answers you agree on.

One member of your group will be asked to tell the rest of the class what you have decided. Choose someone to do this and make sure that he or she knows what to say. (You will all have a chance to do this during the next few weeks.)

QUESTIONS

You have just watched some common appliances working.

1. Where does the energy come from to make the appliances work?

2. In each case, what is happening to the energy?
   i.e. What does the energy do?

3. Where does the energy go to?

4. Do all of the appliances use the same amount of energy?
   If not, which do you think uses most?
   Which uses least?

Energy for the consumer

3

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
How much energy do we use?	Introduce the activity:	Students rank a list of common domestic activities in terms of the amount of electrical energy needed (working in groups). A vote is taken on the devices using most and least energy, and the votes recorded.	for each group: cards describing common domestic activities	
How can we measure the energy we use?	Introduce the next activity: to compare the energy used by different appliances running for the same length of time. The appliances are plugged into the meter as a class demonstration. Help students to compare their results, emphasise that the slope of the line is a measure of how quickly the energy is transferred, i.e. a measure of power. Demonstrate power rating on devices, and suggest that time and power determine electricity used and therefore cost.	Students perform the experiment taking readings from the demonstration. (Two students from the class are near to the meter and clap their hands for each revolution of the wheel; two representatives from the class record timing. Groups of students draw up graphs for two of the appliances after the demonstration has finished.	domestic electricity meter (240V), stopwatches 2 or 3kW kettle 600W hairdryer, 1kW drill iron graph paper for each group	

Homework suggestions: Worksheet: 'Measuring energy'
Given power ratings for appliances and times for completion of tasks, students are asked to rank activities in terms of energy needed e.g. boiling kettle (1.5kW; 4 mins), drying hair (750W; 15 mins), watching East Enders (40W; 30 mins), vacuum cleaning lounge (900W; 10 mins).

The scheme in action : restructuring

3

Aims of the lesson

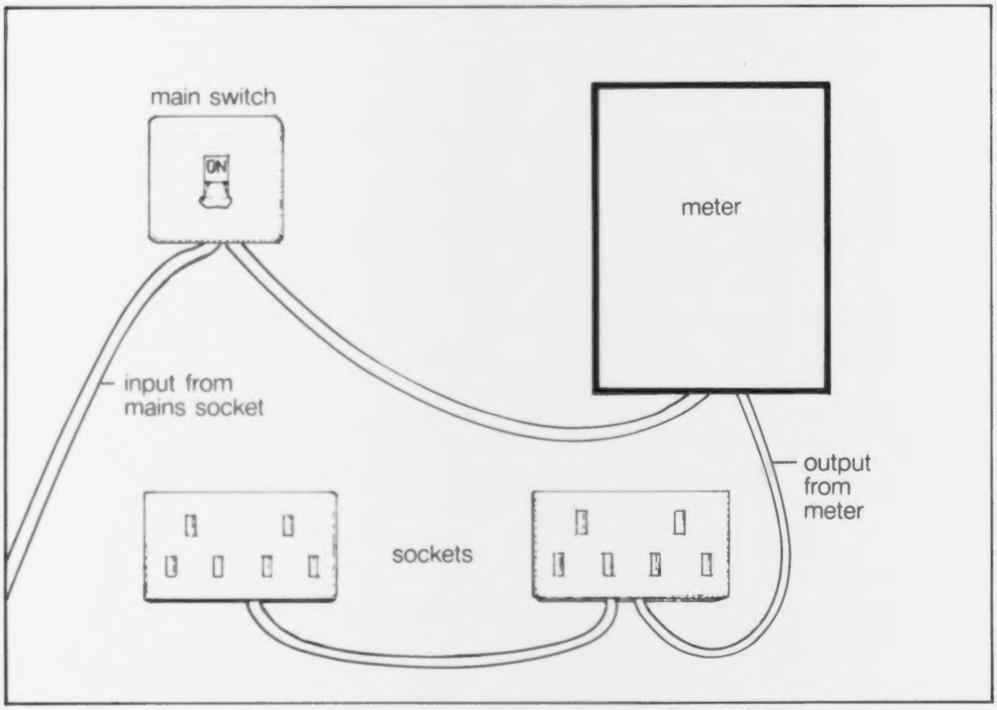
This lesson introduces the idea of measuring energy, emphasising energy as a quantitative, rather than qualitative concept. It also explores the idea that different devices transfer energy at different rates, and that total energy transferred, and hence cost, depends on both the time for which the appliance is used, and the rate at which it transfers energy.

Timings

The card sort is intended to be a quick (5-10 minutes) activity. The bulk of the lesson focusses on the pupil demonstration and discussion, and on graph work.

Practical notes

A suitable layout for a mounted electric meter is:



The meter and attached devices could be protected by using a residual current circuit breaker.

Make sure that the input cable from the mains is long enough to reach a socket when the meter is in use on the front bench.

Make sure that the devices chosen for metering show a range of power consumptions, and that the devices which have low power ratings turn the wheel on the meter fast enough to maintain interest (30 turns per minute is about the minimum). Ensure that the devices are performing the tasks that they were designed to do e.g. make the egg whisk actually whisk an egg!

Try to organise the class so that as many of the students as possible can see the meter. Change the students who are involved in the demonstration after metering each appliance, to share the workload. The student drawing the graph may need some help from you, or you could ask two students to work together. (Large graph paper is available and is preferable to students drawing on the blackboard.)

The iron might need to be turned on before the experiment so that it switches off at least once during the period that it is metered. Use it on its highest setting so that it turns on and off most frequently.

The graph, once drawn, is a useful basis for discussion, which could focus on:

- what does the steepness mean?
- what determines total consumption?
- what does a thermostat do?

Students' response

Some of the ideas about energy consumption of different appliances revealed by the card may be unexpected. For example, they may focus on the duration of the activity, or on the number of simultaneous outputs (e.g. the television gives sound, light and heat, whereas the kettle gives only heat). Some students said that the television would use most energy because it was far away from the transmitter.

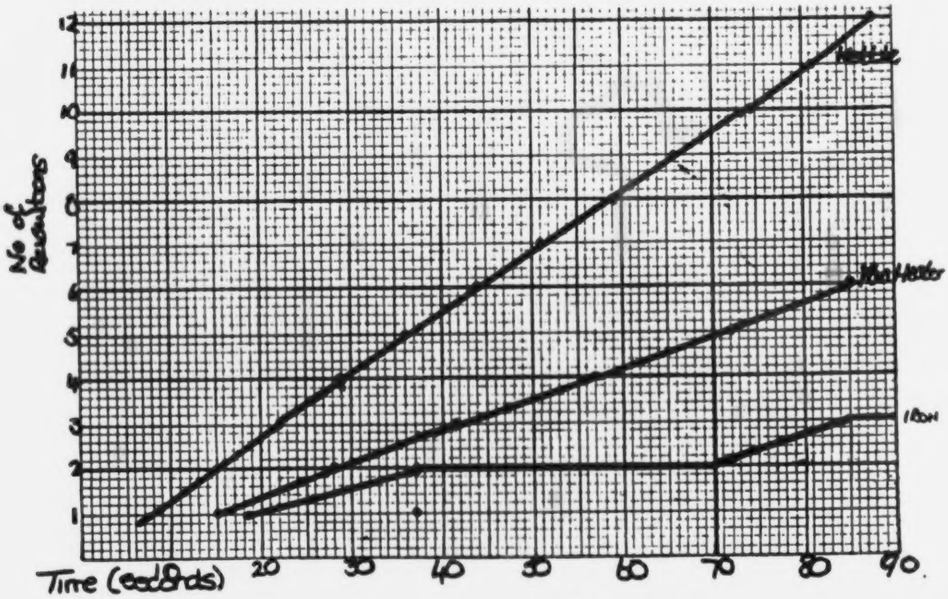
The metering activity works well with most third year children, but some older classes might feel frustrated at the lack of personal involvement. (A class set of five or six meters would help here!)

Typical results might look like this. Students initially tend to think that the iron must be broken when the wheel stops turning. How can something be plugged in and switched on and yet not use energy?!

Measuring Electricity Energy

Time (Seconds)

No of Revolutions	Kettle.	Fan Heater	IRON.	
0	0	0	0	
1	7	15	18	
2	15	28	37	
3	22	42		
4	29	56.		
5	36	1.12		
6	44	1.25		
7	51	1.40		
8	59	1.64		
9	1.06	2.08		
10	1.14	2.22.		
11	1.21	2.36.		
12	1.25	2.80		



Cards describing domestic activities

3

Shaving with an
electric razor
(time: 5 minutes)

Vacuum cleaning
the lounge
(time: 10 minutes)

Lighting the lounge
for half an hour

Boiling enough water
for 5 mugs of tea
in a kettle
(time: 4 minutes)

Drying hair with a
hair dryer
(time: 15 minutes)

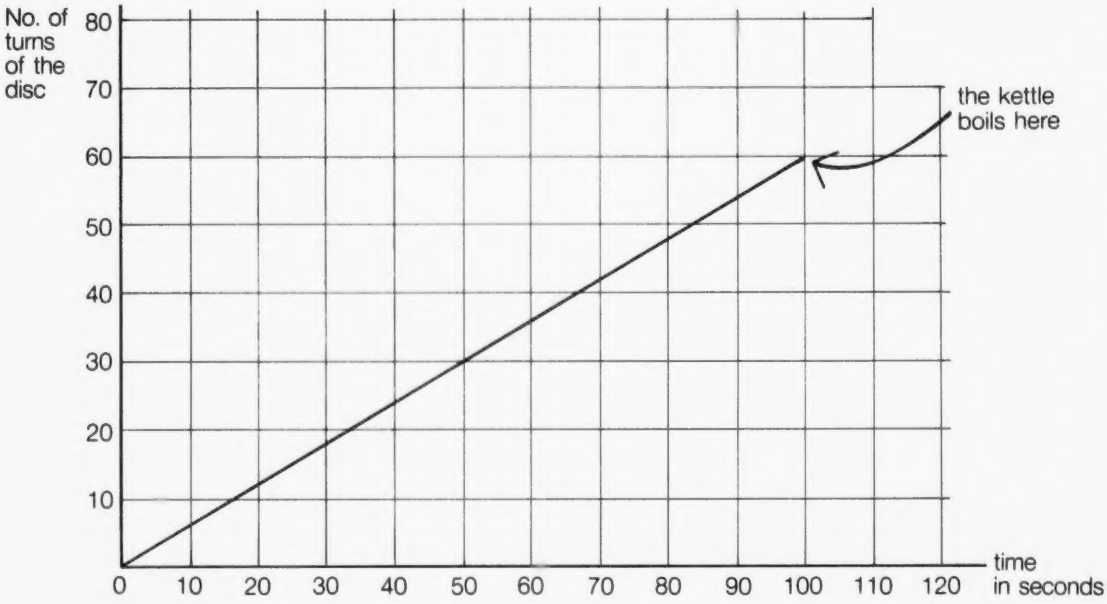
Watching an episode
of "EastEnders"

Measuring energy

3

The graph below shows the amount of electrical energy used by Mr. Brown as he boils his kettle for his mid-morning cup of tea.

The electrical energy has been measured by counting the number of turns of the disc on his electricity meter.



1. How long (in seconds) does the kettle take to boil?

2. How many seconds pass before the disc on Mr. Brown's meter has gone through ten complete turns?

3. After one minute, how many complete turns has the disc on his meter gone through?

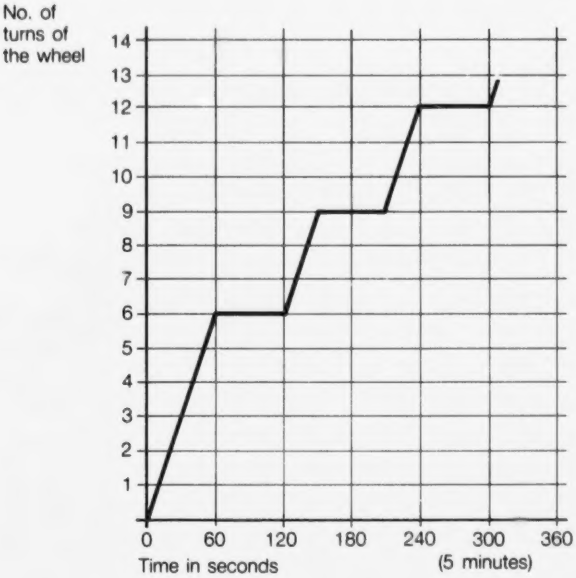
4. How many complete turns has the disc on his meter gone through when the kettle boils?

5. If each turn of the disc means that Mr. Brown has spent 1/100 of a penny, how much does it cost him to boil the water for a cup of tea?

Measuring energy (continued)

3

Later that morning, Mr. Brown decides to iron his cotton shirts. He switches on his iron puts it on the 'cotton' setting and waits for it to get hot enough to start, but he forgets to check it until five minutes later. The graph shows what happens to the disc on his electricity meter during this time.



Use the graph to help you to answer these questions.

6. What happens to the iron 60 seconds after it is switched on?

7. Why does this happen?

8. What happens to the iron between 60 and 120 seconds?

9. When Mr. Brown returns to start ironing his shirts, how hot will the iron be? Will it be
   - too hot to iron his shirts?
   - just hot enough to iron his shirts?
   - too cool to iron his shirts?

   Explain your choice.

10. If Mr. Brown had set his iron to a cooler setting, where would the line on the graph be? Draw a sketch to show what you think (to help you, the line should start where the graph above has been marked with a cross).

Energy for the consumer

4

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What do we pay for when we use energy?	Introduce the activity by discussing different types of meter (dial and digital). Summarise the results.	Students work in groups on meters and bills worksheet. One or two groups report to the rest of the class.	for each group: worksheet: 'Paying for energy (reading meters)'	
	Analyse copies of gas and electricity bills, mentioning estimated bills.	Students work in groups on bills worksheet, using gas and electricity board leaflets where available. One or two groups report to the rest of the class.	Leaflets from gas and electricity boards if available.	
	Point out that these fuels are paid for in different units, and suggest that there is a need for a common unit for comparison: the joule.		worksheet: 'Paying for energy (understanding bills)'.	
Who uses most energy?		Students are given a set of cards showing energy bills (gas and/or electrical) for four customers, and a list of four different locations and lifestyles. In groups, they match locations to customers, listing the factors which they have taken into consideration, and making suggestions as to how the bills might be reduced.	for each group: instruction sheet: 'Paying for energy (who pays most?)' plus bills for sorting large sheets of paper	
	Act as chairperson during reporting session, summarise ideas arising from the students.	One person from each group reports back to the rest of the class.		

The scheme in action : restructuring 4

Aims of the lesson

Lesson four is designed to reinforce and extend the ideas that energy can be measured and that we have to pay for it. Students look at the format and terms used by energy suppliers in their bills, and explore the idea that the amount of energy used depends on environment and lifestyle.

Timings

The two worksheet activities 'reading meters' and 'understanding bills' are each intended to take up about 15-20 minutes, leaving the rest of the lesson (20-30 minutes) for the 'who pays most' activity.

Practical notes

You may find OHP transparencies of 'real' bills useful to analyse with the class. Gas bills are generally more difficult to understand than electricity bills.

The lesson involves students in manipulating a large number of different pieces of paper. You might find colour coding useful.

Leaflets on reading meters and understanding bills are available from energy suppliers. Additional information is available from:

British Gas Education Service
P.O. Box 46
Hounslow
Middlesex TW4 6NF

Understanding Electricity
The Electricity Council
30 Millbank
London SW1P 4RD

If there is time, groups could also be asked to consider why energy bills have fixed charges.

Students' response

Matching bills to consumers is generally enjoyed by students, and they usually manage to get it 'right' fairly quickly. However, you may need to emphasise the reasons for their decisions in the reporting back session, in order to extend their initial reasoning which may be superficial:

Customer T lives in a large house with gas central heating Reasons being that he has a high gas bill of £251·70

Costomer Q lives in a small house in the country, high up on the side of the more. The reason for this is because she has ~~all~~ electric central heating and her bill was £222.09.

customer P lives alone in a flat she has the lowest bill £3-89

Customer S lives in an average size terraced house reasons being that her gas and electric are quite high Electric bill is £58·69.

Paying for energy

4

Reading meters

When Miss Smith looked at her electricity meter in March, the meter showed 36916 units.

When Miss Smith's meter was read by a meter reader from the electricity board in June, the meter reading was 37728 units.

1. How many units of electrical energy had Miss Smith actually used since March?

2. If each unit costs 6p, how much would she have to pay for the units she used?

When the meter reader came to read the meter in September, he could not get into the house because Miss Smith was out at work, so he had to estimate how many units she was likely to have used.

When Miss Smith received her bill in September, it said that her estimated reading was 733 units.

When she read the meter, the meter reading was 38551 units.

3. Was Miss Smith's estimated meter reading for more or less electrical energy than she had actually used?

4. What was the difference in units?

5. What was the difference in cost?

Paying for energy

4

Understanding bills

The bills on this page are not real; they use easier numbers to keep the arithmetic straightforward. Copy and complete the bills; a dotted line (.....) is printed where you need to write something.

ELECTRICITY BILLS

Bill A

PRESENT	PREVIOUS	UNITS	FIXED CHARGE	AMOUNT
15600	15300	.... @ 6p	£10.00	....

Bill B

PRESENT	PREVIOUS	UNITS	FIXED CHARGE	AMOUNT
34569	34333	.... @ 6p	£10.00	....

GAS BILLS

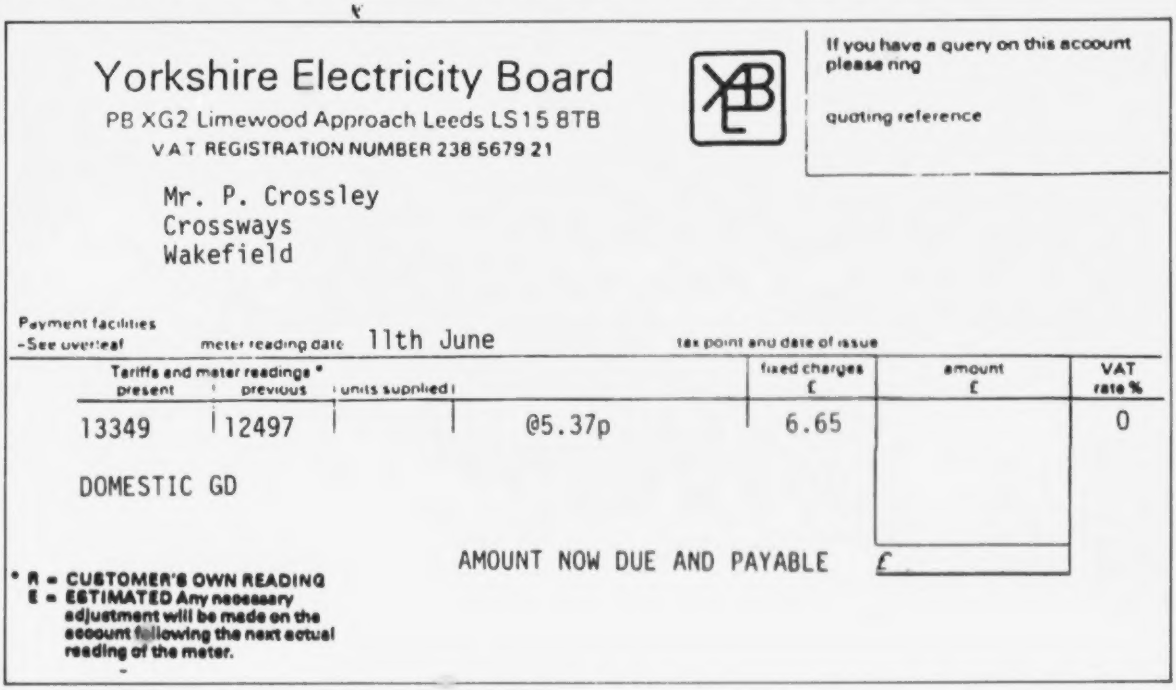
Gas bills are based on how many THERMS of gas energy have been used. The therm is a very old fashioned unit of energy and is now only used by British Gas.

Bill C

PRESENT	PREVIOUS	CUBIC FEET	THERMS	CHARGES (£)
5600	5500	100	105	....
TARIFF 40.00 pence per therm.			STANDING CHARGE	9.20
			TOTAL	....

Understanding bills (continued)

The electricity bill on this page is for Mr. Crossley, who lives in Wakefield. Work out how much he has to pay for the electricity he has used in the last quarter (i.e. in the three months before the date on the bill).



Yorkshire Electricity Board
PB XG2 Limewood Approach Leeds LS15 8TB
VAT REGISTRATION NUMBER 238 5679 21

If you have a query on this account please ring

quoting reference

Mr. P. Crossley
Crossways
Wakefield

Payment facilities
-See overleaf

meter reading date 11th June

tax point and date of issue

Tariffs and meter readings * present	previous	units supplied		fixed charges £	amount £	VAT rate %
13349	12497		@5.37p	6.65		0
DOMESTIC GD						

AMOUNT NOW DUE AND PAYABLE £

* **R = CUSTOMER'S OWN READING**
E = ESTIMATED Any necessary adjustment will be made on the account following the next actual reading of the meter.

TO HELP YOU:

You may find Mr. Crossley's bill easier to understand if you follow these steps:

1. By looking at the 'present' and 'previous' meter readings work out how many units of electricity he has used.
2. Work out how much he has to pay, using the cost of one unit (this is shown on the bill).
3. Add on the extra fixed charge. This will give you the total amount due to be paid to the Yorkshire Electricity Board.
4. Why do you think that gas and electricity suppliers have fixed charges?

Paying for energy

4

Who pays most?

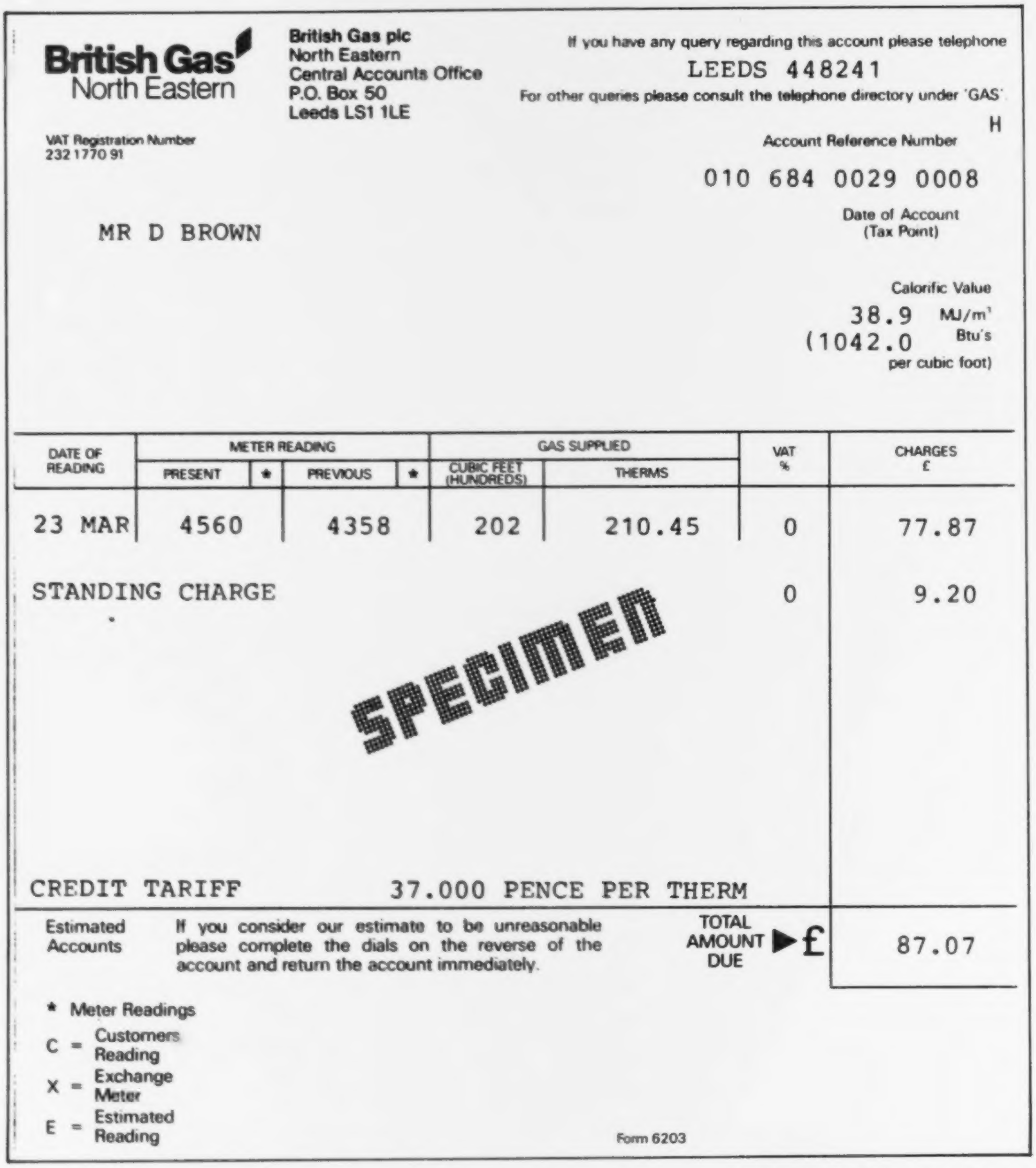
Here are the gas and electricity bills for four customers who are called Mr. Brown, Miss White, Mr. Black and Mrs. Green. The bills are for the winter months.

One of these customers lives in a large house with gas central heating.
Another lives in a small house in the country, high up on the side of a moor, with electric central heating.
Another is a single person living in a flat.
Another has a family and lives in an average sized terrace house.

Your problem is to decide which customer lives in which house.
Write down your answers AND give reasons why you chose these houses for these customers.

What features of your home help to keep energy costs low?

What could be done to your home to reduce energy costs?



British Gas
North Eastern

British Gas plc
North Eastern
Central Accounts Office
P.O. Box 50
Leeds LS1 1LE

If you have any query regarding this account please telephone
LEEDS 448241
For other queries please consult the telephone directory under 'GAS'.

H

VAT Registration Number
232 1770 91

Account Reference Number
010 684 0029 0008

MR D BROWN

Date of Account
(Tax Point)

Calorific Value
38.9 MJ/m³
(1042.0 Btu's
per cubic foot)

DATE OF READING	METER READING				GAS SUPPLIED		VAT %	CHARGES £
	PRESENT	*	PREVIOUS	*	CUBIC FEET (HUNDREDS)	THERMS		
23 MAR	4560		4358		202	210.45	0	77.87
STANDING CHARGE							0	9.20
CREDIT TARIFF			37.000 PENCE PER THERM					

SPECIMEN

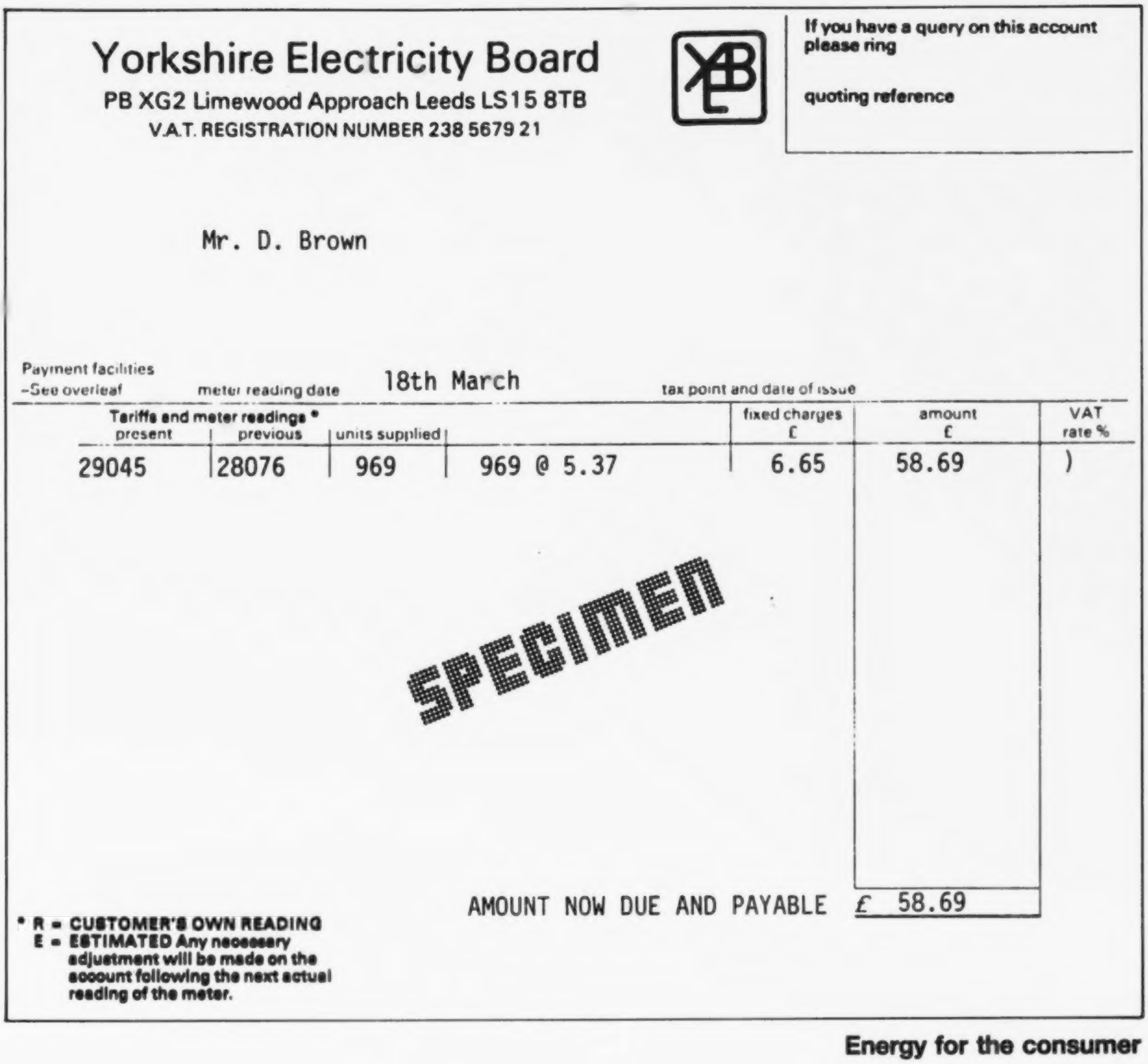
Estimated Accounts — If you consider our estimate to be unreasonable please complete the dials on the reverse of the account and return the account immediately.

TOTAL AMOUNT DUE ▶ £ 87.07

* Meter Readings
C = Customers Reading
X = Exchange Meter
E = Estimated Reading

Form 6203

Energy for the consumer



Yorkshire Electricity Board
PB XG2 Limewood Approach Leeds LS15 8TB
V.A.T. REGISTRATION NUMBER 238 5679 21

If you have a query on this account please ring

quoting reference

Mr. D. Brown

Payment facilities
–See overleaf

meter reading date 18th March

tax point and date of issue

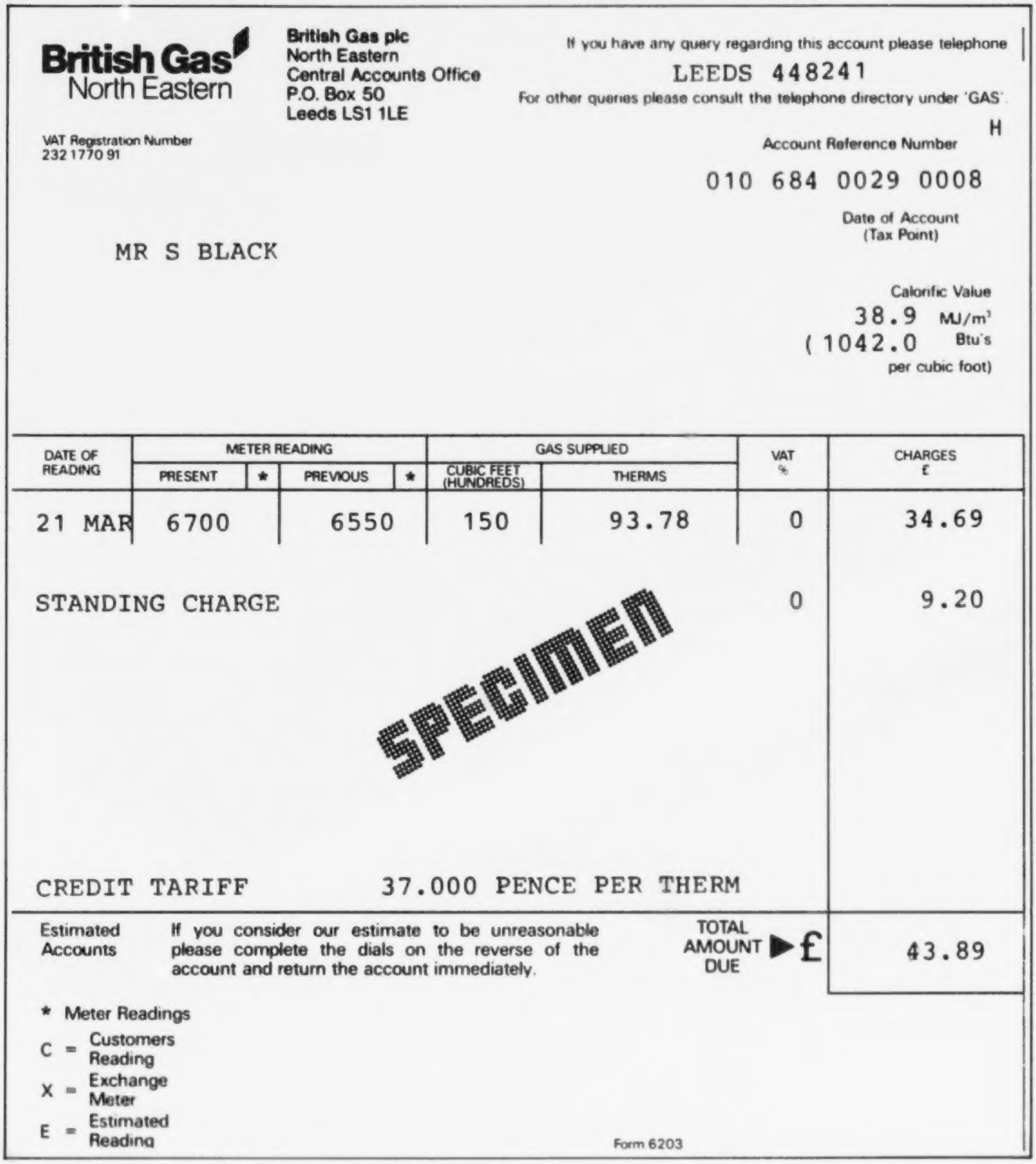
Tariffs and meter readings * present	previous	units supplied		fixed charges £	amount £	VAT rate %
29045	28076	969	969 @ 5.37	6.65	58.69	)

SPECIMEN

AMOUNT NOW DUE AND PAYABLE £ 58.69

*** R = CUSTOMER'S OWN READING**
E = ESTIMATED Any necessary adjustment will be made on the account following the next actual reading of the meter.

Energy for the consumer



British Gas
North Eastern

British Gas plc
North Eastern
Central Accounts Office
P.O. Box 50
Leeds LS1 1LE

If you have any query regarding this account please telephone
LEEDS 448241
For other queries please consult the telephone directory under 'GAS'.

H

VAT Registration Number
232 1770 91

Account Reference Number
010 684 0029 0008

Date of Account
(Tax Point)

MR S BLACK

Calorific Value
38.9 MJ/m³
(1042.0 Btu's
per cubic foot)

DATE OF READING	METER READING				GAS SUPPLIED		VAT %	CHARGES £
	PRESENT	*	PREVIOUS	*	CUBIC FEET (HUNDREDS)	THERMS		
21 MAR	6700		6550		150	93.78	0	34.69
STANDING CHARGE							0	9.20

SPECIMEN

CREDIT TARIFF 37.000 PENCE PER THERM

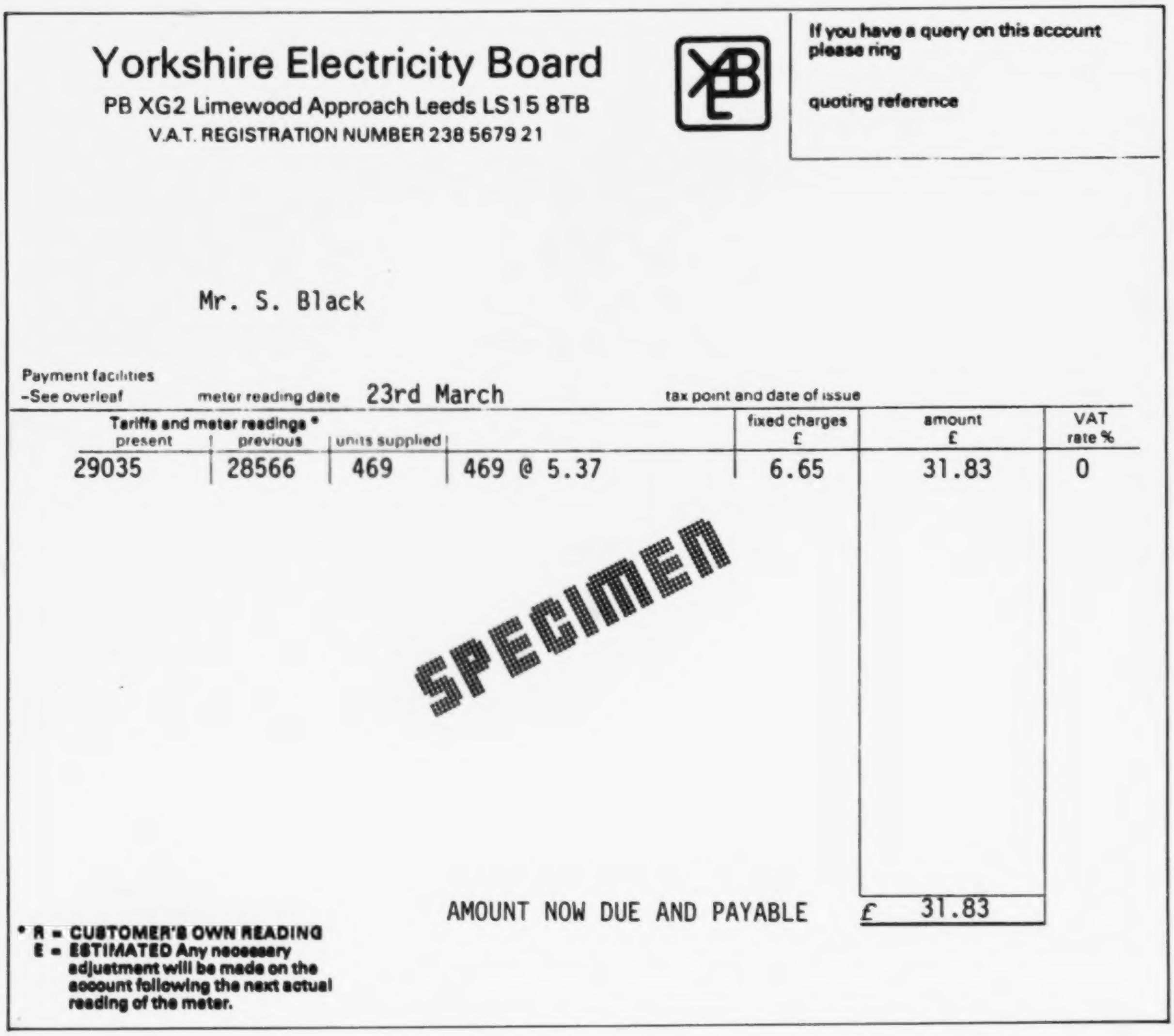
Estimated Accounts: If you consider our estimate to be unreasonable please complete the dials on the reverse of the account and return the account immediately.

TOTAL AMOUNT DUE ▶ £ 43.89

* Meter Readings
C = Customers Reading
X = Exchange Meter
E = Estimated Reading

Form 6203

Energy for the consumer



Yorkshire Electricity Board

PB XG2 Limewood Approach Leeds LS15 8TB
V.A.T. REGISTRATION NUMBER 238 5679 21

If you have a query on this account please ring

quoting reference

Mr. S. Black

Payment facilities
–See overleaf

meter reading date 23rd March

tax point and date of issue

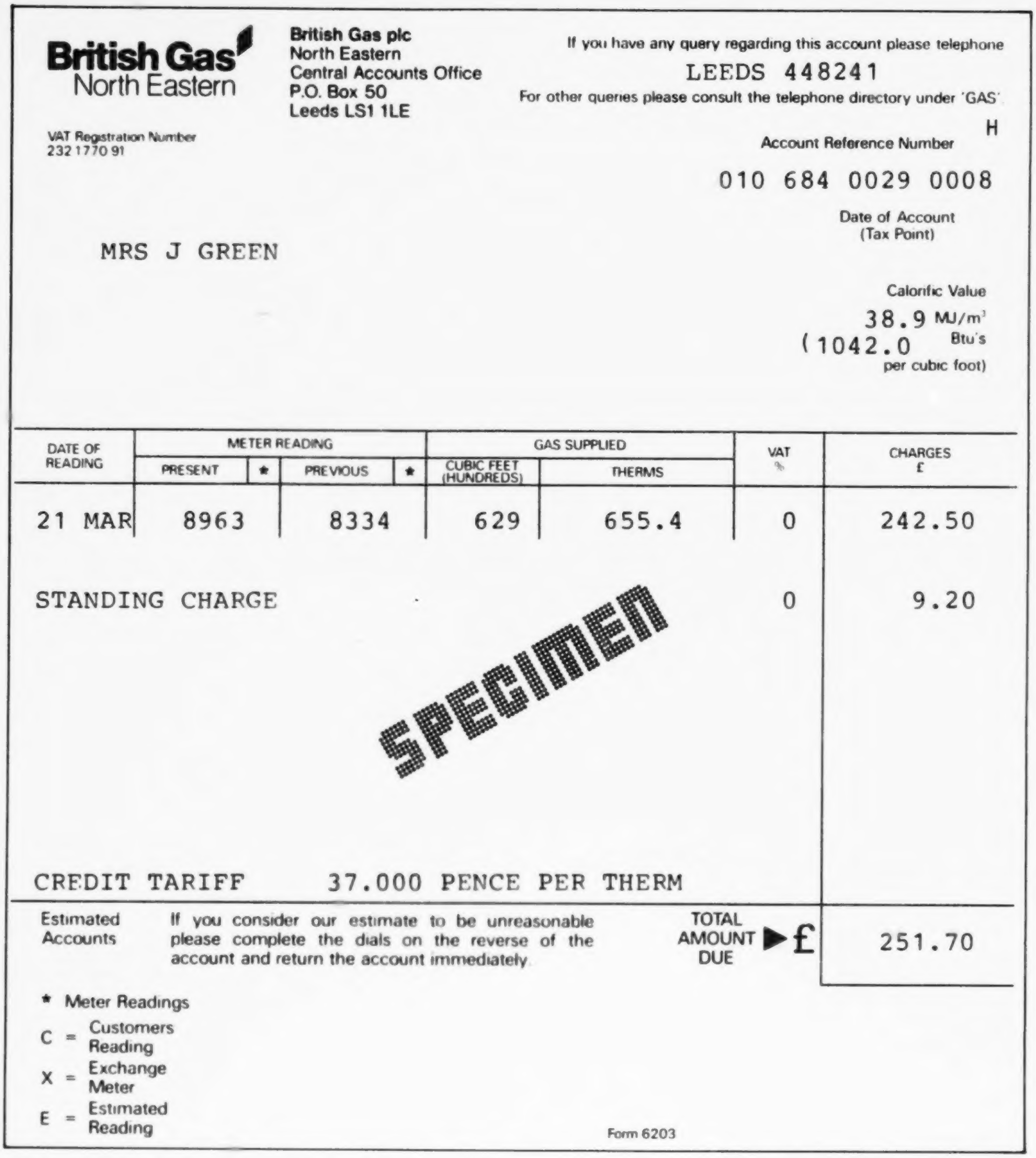
Tariffs and meter readings *				fixed charges	amount	VAT
present	previous	units supplied		£	£	rate %
29035	28566	469	469 @ 5.37	6.65	31.83	0

SPECIMEN

AMOUNT NOW DUE AND PAYABLE £ 31.83

*** R = CUSTOMER'S OWN READING**
E = ESTIMATED Any necessary adjustment will be made on the account following the next actual reading of the meter.

Energy for the consumer



British Gas
North Eastern

British Gas plc
North Eastern
Central Accounts Office
P.O. Box 50
Leeds LS1 1LE

VAT Registration Number
232 1770 91

If you have any query regarding this account please telephone
LEEDS 448241
For other queries please consult the telephone directory under 'GAS'

H

Account Reference Number
010 684 0029 0008

Date of Account
(Tax Point)

MRS J GREEN

Calorific Value
38.9 MJ/m^3
(1042.0 Btu's
per cubic foot)

DATE OF READING	METER READING				GAS SUPPLIED		VAT %	CHARGES £
	PRESENT	*	PREVIOUS	*	CUBIC FEET (HUNDREDS)	THERMS		
21 MAR	8963		8334		629	655.4	0	242.50
STANDING CHARGE							0	9.20
CREDIT TARIFF 37.000 PENCE PER THERM								

SPECIMEN

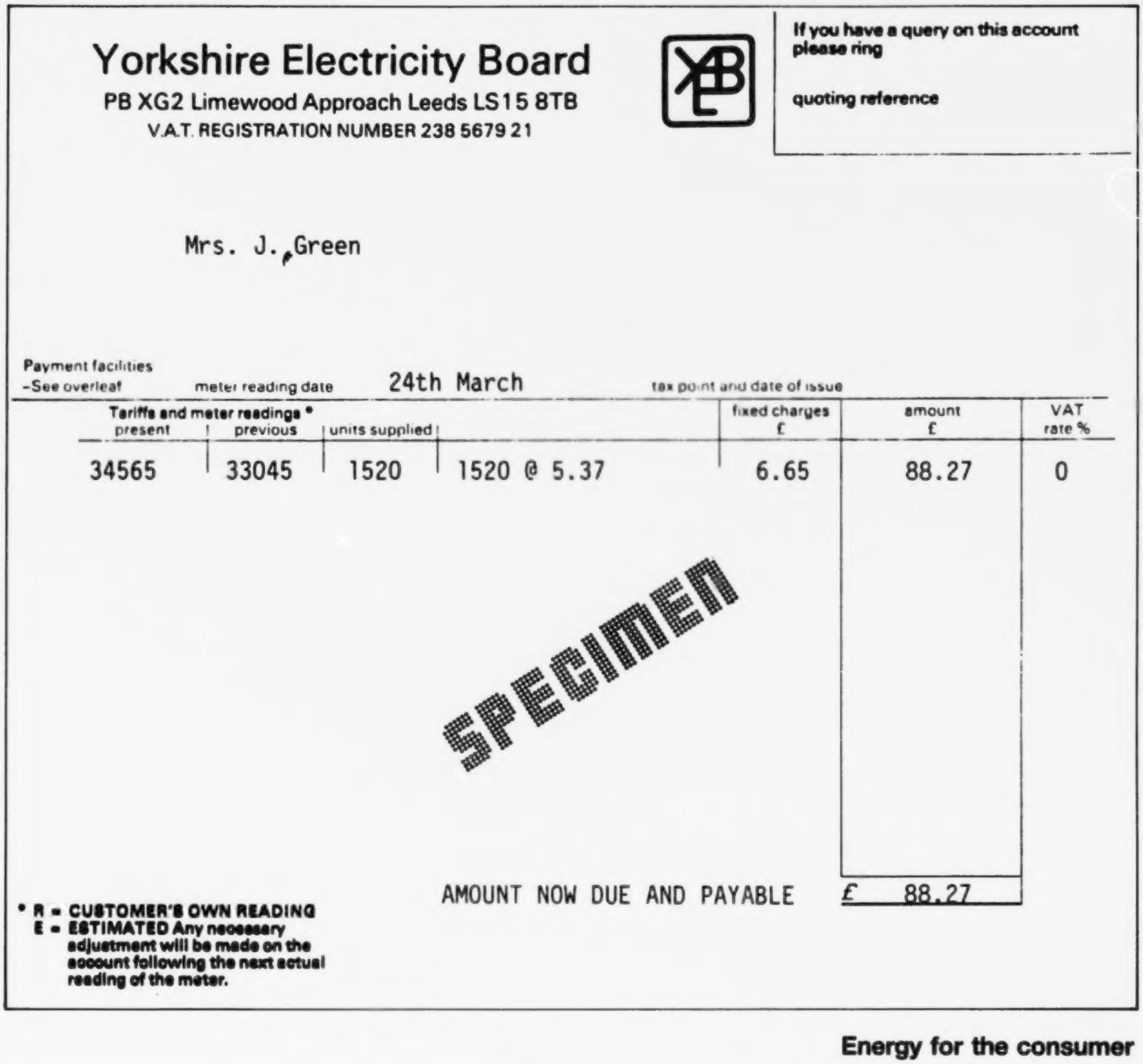
Estimated Accounts — If you consider our estimate to be unreasonable please complete the dials on the reverse of the account and return the account immediately.

TOTAL AMOUNT DUE ▶ £ 251.70

* Meter Readings
C = Customers Reading
X = Exchange Meter
E = Estimated Reading

Form 6203

Energy for the consumer



Yorkshire Electricity Board
PB XG2 Limewood Approach Leeds LS15 8TB
V.A.T. REGISTRATION NUMBER 238 5679 21

If you have a query on this account please ring

quoting reference

Mrs. J. Green

Payment facilities
–See overleaf

meter reading date 24th March

tax point and date of issue

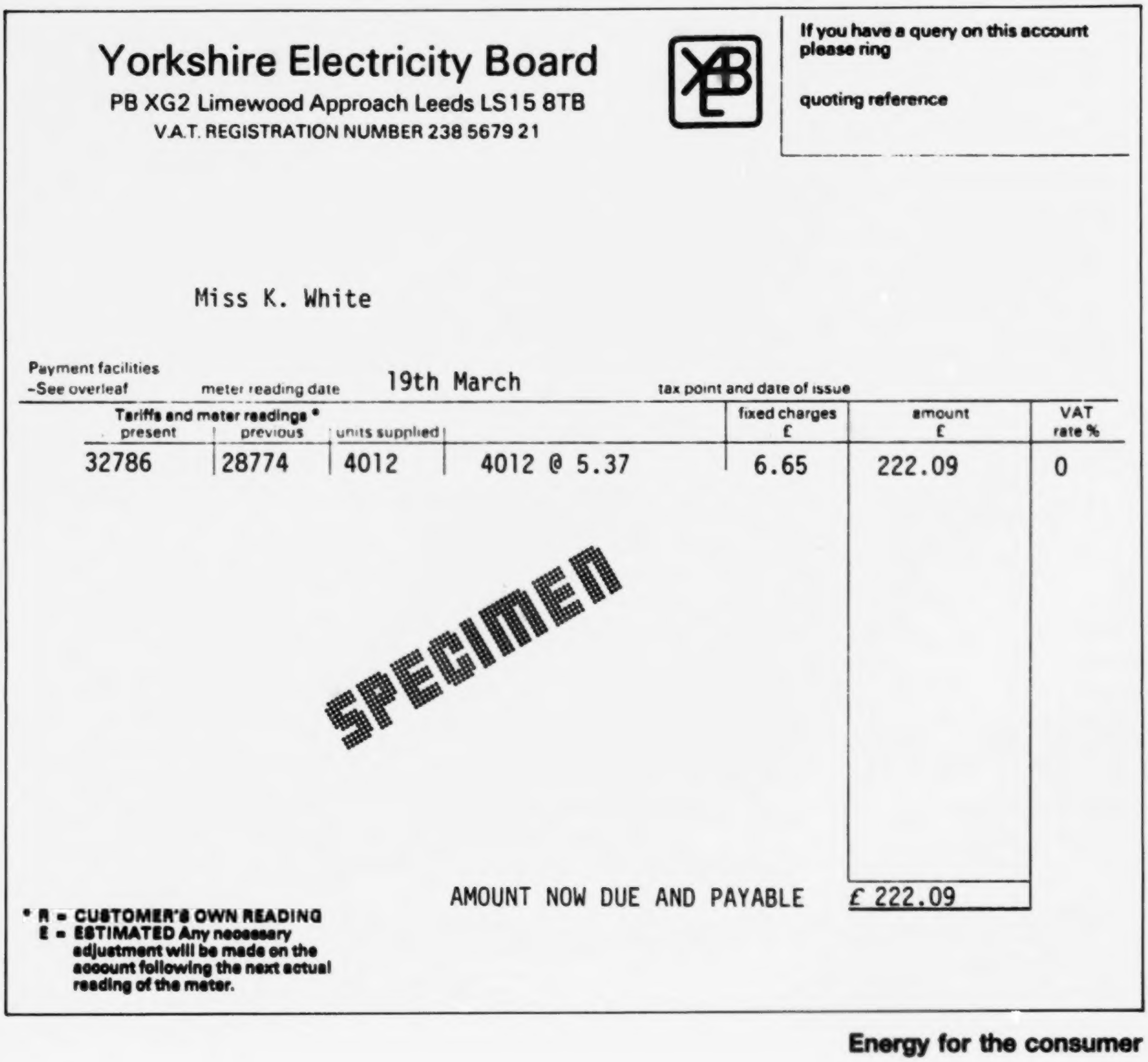
Tariffs and meter readings * present	previous	units supplied		fixed charges £	amount £	VAT rate %
34565	33045	1520	1520 @ 5.37	6.65	88.27	0

SPECIMEN

AMOUNT NOW DUE AND PAYABLE £ 88.27

* R = CUSTOMER'S OWN READING
E = ESTIMATED Any necessary adjustment will be made on the account following the next actual reading of the meter.

Energy for the consumer



Yorkshire Electricity Board

PB XG2 Limewood Approach Leeds LS15 8TB
V.A.T. REGISTRATION NUMBER 238 5679 21

If you have a query on this account please ring

quoting reference

Miss K. White

Payment facilities
-See overleaf

meter reading date 19th March

tax point and date of issue

Tariffs and meter readings * present	previous	units supplied		fixed charges £	amount £	VAT rate %
32786	28774	4012	4012 @ 5.37	6.65	222.09	0

SPECIMEN

AMOUNT NOW DUE AND PAYABLE £ 222.09

*** R = CUSTOMER'S OWN READING**
E = ESTIMATED Any necessary adjustment will be made on the account following the next actual reading of the meter.

Energy for the consumer

Energy for the consumer

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What happens to energy when we use it?		One student brings a bicycle into the lesson, and rides it across the classroom.	bicycle space!	
	Class discussion focusses on the energy changes involved in starting, and especially stopping, the bicycle. Help students to develop parallel descriptions of events (observation) and energy transformations, and keep the focus of the discussion on 'where has the energy gone when the bicycle has stopped?'			
Is all the energy we pay for useful?	Offer help where necessary, advise students to write down what they see before they consider energy changes. Students can be asked to discriminate beteen useful and unwanted energy transfers.	Students work in pairs tracing energy changes and mapping them onto observed events for a number of phenomena, for instance boiling a kettle, using a vacuum cleaner, playing a musical instrument etc. Students write their description and arrow diagrams on large sheets of paper, to help them in reporting back to the class.	Instruction sheet: 'Energy transfer' two for each group. Appliance suggestions: kettle vacuum cleaner guitar slide projector candles torch water pump flash gun microphone tape recorder hairdryer gaz stove	
	Summarise and lead the discussion, pointing out that heat is not always wanted, but is always produced, and referring back to the bicycle demonstration.	One person from each group reports back to the class, showing their 'observations' and energy transfer diagram for one device (for each device, comparison with a second group's ideas is preferable, so that any differences of opinion can be discussed and resolved.	large sheets of paper for each group.	

The scheme in action : restructuring 5/6

Aims of the lessons

These lessons are designed to introduce and explore the ideas of energy transfer, conservation, degradation and efficiency through an arrow diagram convention which helps students to visualise the variety of energy transformations occurring when energy is transferred. Examples are used in which energy conservation might be seen as reasonable and these are followed by examples in which it is less obvious. The arrow diagram notation is intended to help students to address the questions:

- which energy transfers have taken place?
- where was the energy originally?
- where is the energy now?
- which of these transfers are useful?
- intuitively how much energy is being transferred in a useful way?

Timings

Most of the first lesson can be spent on producing an arrow diagram for a device such as a bicycle, finishing off the lesson with students starting work on their own diagrams for domestic devices.

At the beginning of the second lesson, groups of students finish off their diagrams. Half to two thirds of the lesson should be devoted to presentations of descriptions, diagrams and devices to the class.

Practical notes

If a bike is used, remember to make arrangements the day before!
Again, there are obvious safety aspects to consider when using 'real' devices in a laboratory. Most domestic devices are very safe when they are being used for the purpose for which they were designed. An electric drill is a good device but only for demonstrations. Musical instruments often provoke discussion amongst pupils.

Some students may still think that energy is 'used up' in the case of the bicycle. However by this stage, some students will be prepared to consider 'where has the energy gone?', and their suggestions may help to move the class as a whole towards a 'conserving' view. Introducing the idea of 'useful' energy (which is not conserved in transfer) will help the discussion.

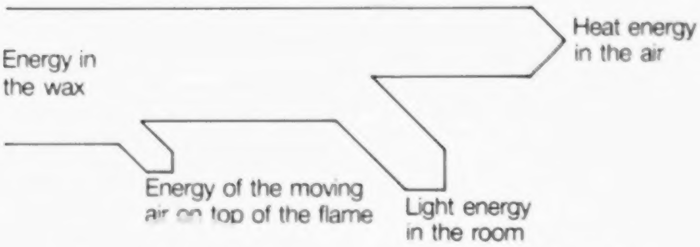
A convenient method of illustrating the 'flow' of energy through a system is the two-level arrow notation which offers great potential in illustrating and exploring the concept of energy.

First level

This is a simple description or 'story' about what happened in the event. The description should avoid any mention of energy as such, "the candle burned and it gave out light and got warm. Some air went up from the top of the flame."

Second level

(example of students' work)



The arrow notation has two key features which you may wish to emphasise:

- The sides of the arrow and sub-arrows should be kept parallel as shown. By making the total thicknesses of the emergent arrows equal to the input, the diagram gives a visual indication that energy is conserved - the concept is implicit in the notation.

- The focus in the diagram should be on the location of the energy - to and from where the energy has been transferred. Energy transformations (i.e. in what form the energy appears) are less important, but can often be inferred from students' labelling of the arrows. The diagram can show as many transfers (and transformations) as the students notice.

Other points to note:

- The first level 'story' should be reasonably complete, and students should be able to map their description onto their arrow diagram.
- Large sketches of arrow diagrams, plus first level descriptions are useful for display work, and form a useful focus for attention when students are attempting to justify their ideas to the rest of the class.
- You could ask students to decide which of the energy forms are 'useful' and so work towards a qualitative concept of efficiency.

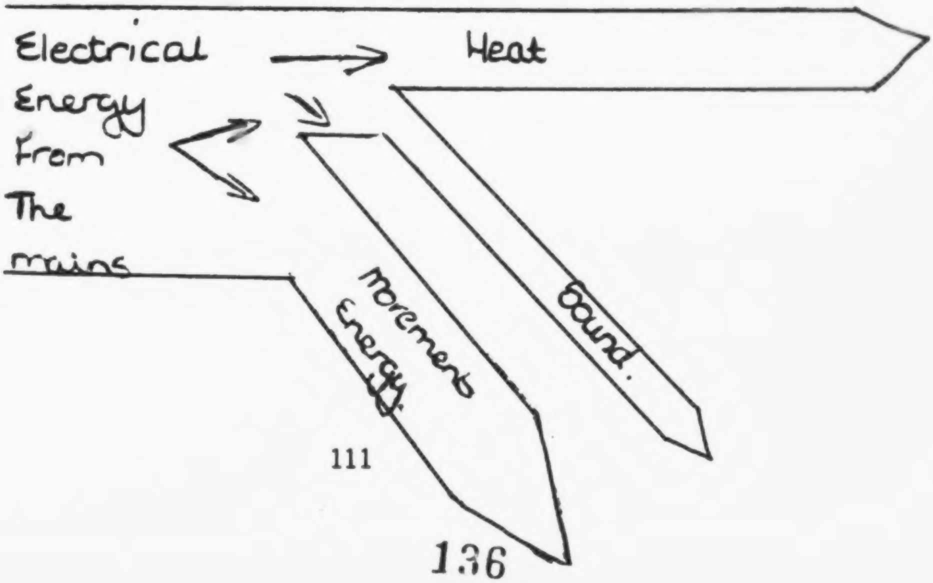
Students' response

Since the word 'conservation' already has many connotations for students; it means looking after wildlife and saving energy, you may wish to focus instead on 'energy accounting' - 'where has the energy gone?'.

Some groups produce arrow notations which focus on the type, not location of energy. Ask the groups to say where the energy is.
For example:

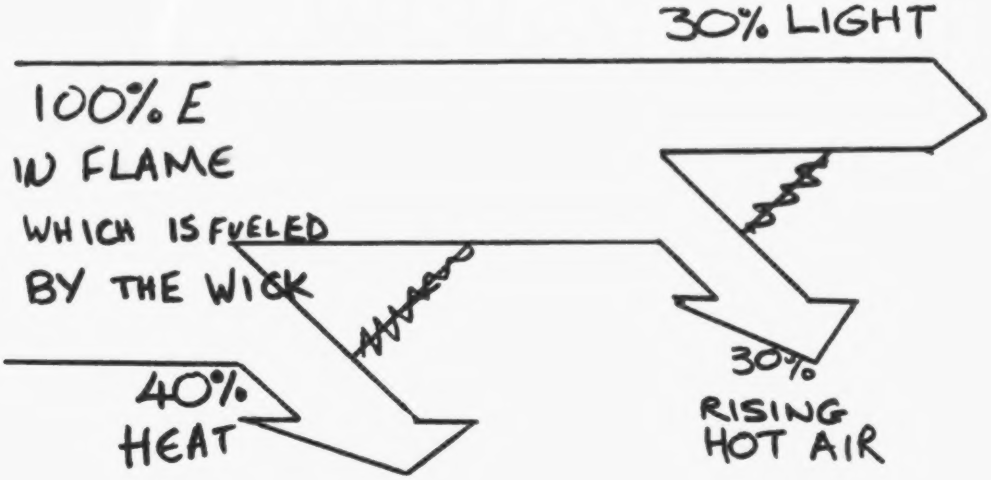
Wisk.

We can see from where we are sat that the beaters are overlaping and that they are turning round. We can hear a noise from the motor. We can feel vibrations from the motor.



We found that some groups spent time arguing about how much energy was transferred at each point in the diagram. Their judgement is based on intuitive ideas about the 'value' of different forms of energy, and opportunities for students to discuss and clarify these ideas are valuable. You could ask the groups how they have decided on the 'allocations' of energy, and how they might check their ideas.

An example of one group's diagram is shown below (amended after discussion with their teacher):



Some groups may need help in producing arrow diagrams which have the key features described previously. For example some groups may produce diagrams with curved or converging arrows, or may not include all of the transfers for the device. Feedback from the rest of the class during the reporting back session usually highlights the inconsistencies.

Energy transfer

5

6

You have already talked about what happens when someone rides a bicycle, then brakes and stops, and you have thought about where the energy comes from and goes to.

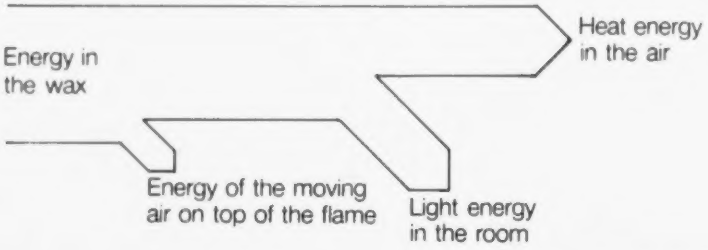
Now write down what you see, feel, hear etc, when you use some of these everyday appliances. One of your group will be asked to talk about your discriptions and arrow diagrams. Choose someone to do this (someone who has not already talked to the rest of the class) and make sure that he or she knows what your ideas are.

Here is an example for an electric drill, drilling a hole in piece of wood. As you can see, some of the energy is transferred to do something useful (like moving the drill bit), but some of the energy is used for something we don't want (like heating the motor). Try to think about usefulness when you draw your arrow diagrams.

Description

A candle is lit. It burned and gave out light, and it got warm.
Air was moving at the top of the flame.

Energy transfers for a candle



Energy for the consumer

Energy for the consumer

7

Focus	Lesson Activities		Equipment	Notes
	For the teacher:	**For the students:**		
What happens to the energy we use to heat things up?	Begin the lesson by making a cup of tea at the front of the class, reviewing the energy transfers as the water boils (reinforcing the ideas raised last lesson). Pose the questions 'What happens if the cup of tea is forgotten?', 'What happens to the energy?'.	Students carry out practical work in their groups.	for each group: beakers water bowls thermometers stopwatches	
	A container of hot water is placed in a larger container of cold water, and students plot temperature - time curves for both hot and cold water on the same graph.		for each group: graph paper	
	Summarise the group reports and help students to make comparisons between the results of different groups.	One person for each group reports back to the class using the graph to describe what happened to the temperatures.		
	Lead a class discussion about where the energy goes as the temperature falls. The experiment is linked back to the cup of tea from the beginning of the lesson, and to lessons 5 and 6 (discussion of 'useful' energy transfers).			

Homework suggestion: Worksheet: 'Energy transfer'.

The scheme in action : restructuring

7

Aims of the lesson

Although children may be sympathetic to the idea of dissipation, a typical intuitive response to the question 'where has the energy gone when something cools?' tends to be simply 'it's gone'. The aim of the lesson is to build up the concept of dissipation from observations.

Timings

We suggest approximately 20 minutes for students to carry out the experiment. The rest of the lesson should be spent drawing graphs and discussing the results.

Practical notes

The students could be encouraged to suggest which variables should be controlled in the experiment.

A beaker of hot water (volume V1, temperature T1) is placed in a bath of cold water (volume V2, temperature T2). Each group has the same V1, T1, T2, but different V2 (i.e. different sized baths). Students record temperatures T1 and T2 every miunute for 15 minutes, plotting temperature-time curves for both temperatures on one graph.

By comparing the curves obtained using different quantities of cold water, the students can predict what might happen with ever increasing volumes of cold material and then extend this to the whole environment. If there is not enough time to draw graphs the same points can still be made using the actual temperature changes.

Focus questions for the class discussion might include:

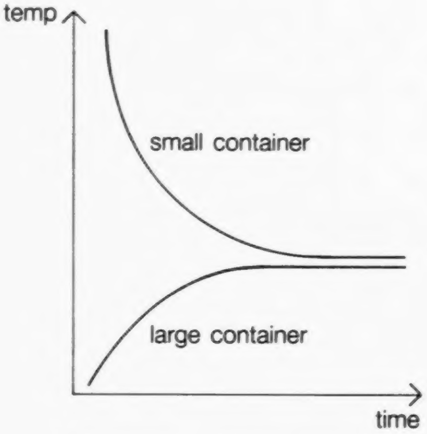
- where does the energy from the hot water go?
- how can you tell?

- why do the graphs look different for different sizes of large container?
- where has the energy from the cup of tea gone (from the beginning of the lesson)?
- why can't you tell?

Students' response

As well as what you might expect them to suggest (size of small container, temperatures) they may come up with questions such as 'how high up should the thermometer be in the container?', 'should the thermometer be moved in the liquid or stationary?' etc.

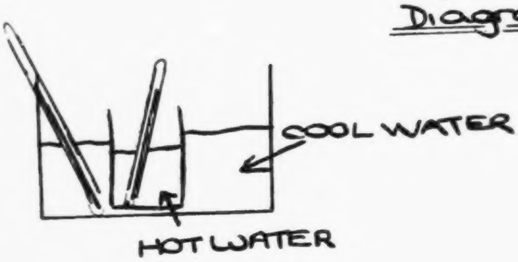
The graphs produced for small containers of cold water will be shaped like the one on the right, but students who use larger containers (e.g. washing-up bowl size) may find that there is no measureable rise in the temperature of the cold water. The results of one such group are shown below.



TIME (MINS)	TEMP OF COOL WATER	TEMP OF HOT WATER
0	16°C	84°C
1	18°C	61°C
2	19°C	50°C
3	20°C	41°C
4	20°C	35°C
5	20°C	31°C
6	20°C	29°C.
7	20°C	26°C
8	20°C	25°C
9	21°C	24.5°C
10	21°C	23°C

Where does heat go to?

Diagram



Energy transfer

7

1. When we drive a car, we use the energy in petrol.
   What do we want the energy to be used for?
   Are there any energy transfers which we don't want, i.e. which aren't useful?
   Draw an arrow diagram showing the energy transfers involved in driving a car, and show which of them you think are useful.

2. Rub a coin on a solid surface (e.g. on a piece of newspaper on a doorstep) for 30 seconds, then put the coin against your cheek.
   What do you feel?
   Where has the coin's energy come from?

   Leave the coin for a minute, then put it against your cheek again.
   What do you feel?
   Where has the coin's energy gone to?

   Could you prove your answer to the last question?
   If so, how could you prove it?
   If you think you can't prove it, can you say why not?

Energy for the consumer

Focus	Lesson Activities		Equipment	Notes	8 9 10
	For the teacher:	**For the students:**			
	Planning and building				
How can we keep as much energy as possible where we want it?	Introduce the house building project by reminding students about the 'Save it' and 'Monergy' campaigns. The intention is for students to design and build energy efficient house, and to be able to justify their designs.	Working in groups, students formulate the criteria used to judge the efficiency of the houses, and the 'rules' for their construction (see over for suggestions).	shoe boxes sellotape clear plastic bags crayons/felt tip pens/marker pens newspaper thermometers 24W bulbs splints scissors storage space lab packs poster paper		
	Hand out material for houses and set a time limit of 1½-2 double lessons for construction.	Students build houses, working in groups, and produce posters justifying their design in terms of the science they have met during the energy topic.			
What have we learned about energy?	At the beginning of lesson 9, review the ideas covered in the topic, so that students can focus on these in their construction.				
	Testing and judging				
		The houses are set up and switched on; whilst they warm up, each group justifies its design to the rest of the class.			
	You may award a small prize for the best result.		prize		

The scheme in action: application and review

8/9/10

Aims of the lesson

The primary intention in these lessons is to give students opportunities to apply their new ideas in a practical situation, and to review what they have learned during the topic.

Timings

Planning and building will probably take two double lessons. About half of the first lesson can be spent negotiating 'rules' as a class, and the rest of the time on constructing the model.

Review: Spend about 15-20 minutes at the beginning of the second house-building lesson in reviewing what students feel they have learned about energy.

Testing and 'judging' is intended to take place in lesson ten. Allow students about ten minutes to make final adjustments to their houses, then about 20 minutes to put together their posters and notes for presentation. Presentations from six or seven groups typically take 30 minutes in total.

Practical notes

Shoe boxes can be obtained fairly easily with prior notice. Students may notice if they are of slightly different sizes. It is useful to have one or two spare boxes available in case a group decides to abandon their design and start again.

You will need the following materials for each group of four students:

1 shoe box
4 large sheets of newspaper
2 clear plastic bags
10 splints (for window frames!)
1 piece (A4 maximum) spare cardboard
sellotape at your discretion

Distribution of materials needs strict control; resist requests for replacements!

It can be a very useful exercise to allow the students to suggest and negotiate the set of rules. Elicit initially a list of what needs to be covered by the rules if the test is to be fair, then devise an agreement on how the class will monitor itself to ensure that groups keep to the contract. The students in one class suggested the following rules:

> That each house should have:
>
> - 2 windows, 5 x 6 cm, not obscured
> - 1 door, 3 x 6 cm, which opens
> - windows not on the same wall
> - a lid, which is the roof and which must be removable
> - a heat source (bulb) mounted half way up one short wall
> - a thermometer mounted half way up the opposite wall to the bulb
> - a card screen positioned so that no radiant heat falls directly onto the thermometer.
>
> All of the boxes should look like houses.

If students do not initially give thought to considerations such as 'where should the windows and door be in relation to the bulb?' and 'what shape of roof is best?' you can introduce these questions during construction to individual groups.

The 'review' session is an opportunity for students to make notes in their exercise books. We suggest that they write down what they feel they have learned about energy, and/or the consensus view of the class. Encourage the students to think about how their ideas have changed during the topic, and to consider how their new ideas can be applied to the design of their houses.

Points may be awarded for appearance, temperature rise and the quality of scientific explanation/justification given. The weighting given to each aspect of the design is at your discretion, but we suggest that extra weight should be given to explanation.

Students' response

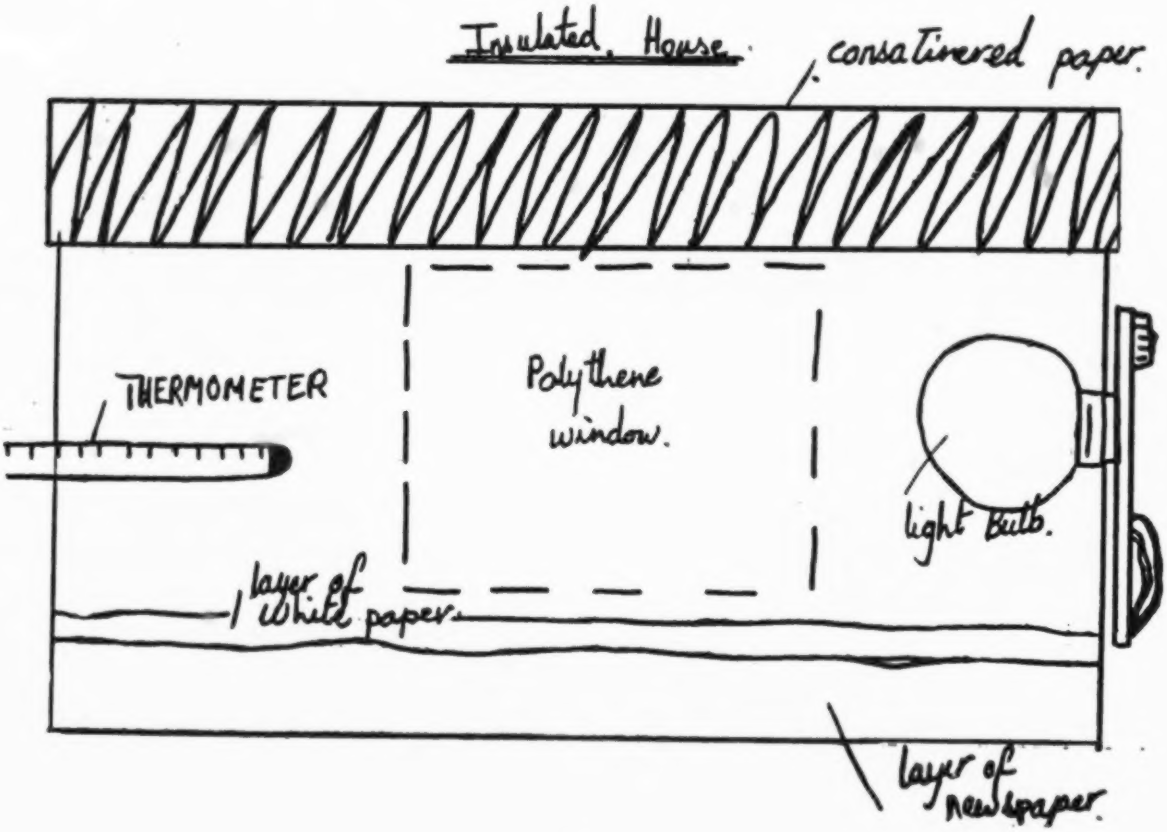
Students usually experience little difficulty in deciding some of the more obvious variables which need to be controlled - size of box, materials (type and quantity) for example. You might find that they are prepared to spend minutes arguing about whether 'curtains' should be up at the windows.

Some groups may attempt to 'bend' the rules to their advantage. You might like to appoint a 'building inspector' from each group to watch out for cheating in an adjacent group.

Innovations like pitched roofs, for example, spread quickly through the class. Encourage students to try different designs from their neighbours.

Keep an eye on the houses during testing; they can start to smoke!

An example of one group's house design is shown below:


Insulated House.
consatinered paper.
THERMOMETER
Polythene window.
light Bulb.
layer of white paper.
layer of newspaper.

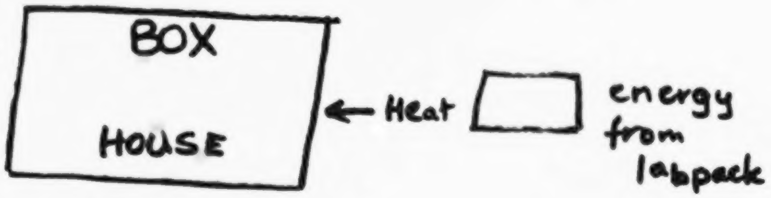
Another group of students include written notes on their poster to help them during the reporting-back session. This group appeared to draw on previous learning about heat transfer, using colour to maximise radiant heat reaching the thermometer, for example. However, the note 'Windows low. Heat rises' illustrates the confusion which can arise.

windows have quatrople glazing which traps
layers of air to keep hot air in

Coloured Roof dark to take in any outside heat.
Coloured top of room white to reflect heat back into
room to thermometer.

archway in wall to one side - to abide by Rules

Shutters on windows
for decoration &
extra insulation



draft excluder (sausage dog) infront of door
furnature includes one table and one chair

Newspaper in middle acting as wall with arch way.

Roof packed with spare pieces of news paper etc .. as
insolation.

Slates on roof, decoration tissue paper flowers

Selotape put all round open edges to prevent air seeping
out

White inside to reflect heat back onto thermometer

Windows low. Heat rises

Materials reference list

LESSON ONE:
slides (some examples are enclosed in this pack)
projector
photographs
for each group:
worksheet: 'What makes a good fuel?'
fuels (e.g. coal, wood, dried peat, charcoal, coke)
goggles
bunsen burners
tripod
gauze
tin lids
heatproof paper
optional: kerosene
petrol
diesel
alcohol
homework: worksheet: 'Choosing fuel'

LESSON TWO:
domestic devices (e.g. kettle, 1kW drill, whisk, 600W hairdryer, curling tongs, 40W bulbs, 100W bulbs, 2-3kW kettle)
for each group:
worksheet: 'Using electrical energy'
poster paper
pens
magazine cuttings
glue
poster paper
storage space
display space

LESSON THREE:
cards describing domestic activities, for each group
domestic electricity meter
stopwatches
2 or 3kW kettle
600W hairdryer
1kW drill
graph paper (with axes marked if necessary) for each group
homework: worksheet: 'Measuring energy'

Materials reference list (continued)

LESSON FOUR:	for each group: leaflets from gas and electricity boards worksheets: 'Paying for energy: reading meters, understanding bills' large sheets of paper
optional, from lesson three:	domestic meter
LESSONS FIVE AND SIX:	bicycle space for demonstration appliances (e.g. kettle, vacuum cleaner, guitar, slide projector, candles, torch, water pump, flash gun, microphone, tape recorder, hairdryer, gaz stove) for each group: large sheets of paper instruction sheet: 'Energy transfer' (two per group)
LESSON SEVEN:	for each group: beakers water bowls thermometers stopwatches graph paper
homework:	worksheet: 'Energy transfer'
LESSONS EIGHT, NINE AND TEN:	for each group: shoe boxes (organise well in advance) sellotape clear plastic bags/sheets crayons/marker pens/felt tip pens newspaper thermometers 24W bulbs splints scissors storage space laboratory packs poster paper
optional:	prize!

SECTION 5

Some reactions to the schemes

Both of the energy schemes invite students to play a more active part in their own learning than that to which they may be accustomed in science. This requires a willingness on your part to use teaching strategies which may be unfamiliar and which are certainly demanding in terms of both time and effort, and a high level of co-operation from students (changes in their science lessons may seem strange to them too!).

This section includes some of the comments made by teachers and students who were involved in developing and trialling the schemes.

5.1 From the teachers

Teachers in the group feel that they have made significant changes in the way they viewed teaching, and in their classroom practice during the development of the materials. Some of their comments are included here.

Understanding

'The approach allows the pupils to participate fully in the lessons and so encourages them to think through problems. This seems to be a positive way to make the children into better "scientists" in the long term.'

'The opportunities provided in the scheme for students to explore their own thinking and the meanings they attach to words was very important, and led in most cases to a substantial gain in understanding of energy. I suspect that difficult concepts in science need more time spent on them if pupils are to be given opportunities to change strongly held views.'

Social skills

'I have been surprised at how students will take their own learning seriously when the pressure to "get the right answer" is reduced.'

'As the scheme progressed, I noted increased willingness on the part of pupils to be involved in the less familiar lesson activities. This was particularly pleasing in the discussion work, where the confidence of the class did noticeably improve, mainly due to the increased tolerance of the pupils for the ideas of others. For the pupils, having their ideas valued seemed relatively new, but their response was very positive.'

'Listening to a class running a plenary reporting back session successfully without any major intervention from me suggests that they do welcome the opportunity to have their own ideas listened to and in turn will listen to others.'

Enjoyment and involvement

'Overall, the pupils were involved in the learning ... to an extent I have not found in more traditional schemes. When asked which topic they had enjoyed most (all our third year groups were asked) my group nearly all chose energy, whereas in other groups the choice was spread over several topics.'

'Pleasantly surprised by how smoothly it went. However, teacher is required to plan carefully and be able to "think on his/her feet". Some of the pupils are excellent lateral thinkers. The course as a whole seemed to be enjoyed by pupils with good group participation.'

> 'The pupils appeared to be enjoying their science, and the spin-off from this was an improvement in their attitude towards other topics. The schemes did involve me in different teaching strategies, which could be more demanding on my time and energy. However, the benefit in terms of a happy and motivated class, who were gaining genuine understanding of difficult concepts, made the effort worthwhile.'

5.2 From the students

Students were asked to comment on the schemes on a number of occasions during the teaching. Here are some of their (written and verbal) comments.

> 'I like it when you are set problems and challenges to solve in small groups, and would like to see more of these. They keep you interested in the lesson.'

also on group work:

> 'You get to see - well, hear - what everybody else thinks and that makes it a lot more interesting than just sitting down and writing loads of pages out.'

> 'I like discussing in the group best, because we are always asking each other questions.'

On posters:

> 'We needed a lot of time to do the poster - well, we needed a lot of time anyway. Yes, I think it was long enough. Just long enough so you weren't getting too bored with it, and you just sort of carried on. You didn't have nothing to do at any time. You always had something to do.'

On practical work:

Interviewer: What do you think is most important about science?

Gary: It's the underlying bit because that's the science part of it, because say if you just explain something and he's given all the science down and you've understood it and you *don't* do a practical, you can still understand it just as well. But if you *just* do a practical and you don't understand it then it doesn't sink in.

Lisa: I think the practical work's best because it's finding things out ... and trying to do it yourself.

Gary: I like the practicals best, but I think the science that's underneath it is most important.

Some students expressed concern towards the end of the topics that they had not been given notes to write in their books:

> 'I think he should have given us a paragraph on energy so we could revise with exams coming up.'

However, they seemed to appreciate the value of writing in their own words:

> 'Because sometimes if he writes it down on the board and it's really complicated and you don't understand it and you ask him and then you write it down in your own words because there's no point writing it down otherwise.'

and most seemed confident that they could write something themselves about what they had learned:

> 'It'd take a bit of thinking about, but I think I'd be able to.'

5.3 From you

We would be interested to hear the reactions of anyone who reads this teaching scheme, and also the reactions of teachers or pupils who have used the scheme in their classrooms.

You may wish to modify these materials for use with particular groups of pupils, or for different areas of scientific content. Again, feedback would be gratefully received.

Please address your comments to:

Angela Brook
Children's Learning in Science Project
Centre for Studies in Science and Mathematics Education
The University
Leeds LS2 9JT Telephone: 0532 431751 ext. 6239

Notes

1. A more detailed description of this phase of the project's work can be found in Driver, R. and Oldham, V. (1986) A constructivist approach to curriculum development in science. *Studies in Science Education*, *13* 105-122

2. Feynman, R. P., Leighton, R. B. and Sands, M. (1963) *The Feynman Lectures in Physics* Vol. I. Addison Wesley, Reading, U.S.A.

3. Solomon, J. (1983) Thinking in two worlds of knowledge. *In*: *Proceedings of International Seminar, 'Misconceptions in Science and Mathematics'*. Cornell University, U.S.A., June 1983.

4. Brook, A. and Driver, R. (1986) The construction of meaning and conceptual change in classroom settings: Case studies on energy. University of Leeds.

5. Solomon, J. (1983) Messy, contradictory and obstinately persistent: a study of children's out-of-school ideas about energy. *School Science Review*, 65, pp. 225-233.

6. Brook, A. and Driver, R. (1984) Aspects of secondary students' understanding of energy: full report. University of Leeds.

7. Duit, R. (1981) Students' notions about the energy concept - before and after physics instruction. *In*: Jung, W., Pfundt, H., Rhoneck, C.V. (Eds) *Problems concerning students' representation of physics and chemistry knowledge*. Proceedings of a workshop held in Ludwigsburg, West Germany. Pedagogische Hochschule, Ludwigsburg (1982).

8. For a more extended discussion of these implications see Bell, B. and Driver, R. (1986) Students' thinking and the learning of science: A constructivist view. *School Science Review*, March 1986.

9. Driver, R., Wells, P. and Brook, A. (1987) Children's Understandings and the Teaching of Energy in Schools. Paper presented at the Energy in the School Curriculum Conference, January 1987.

10. Students' intuitive understanding of energy is similar to a scientist's notion of 'free energy' or useful energy, which does run out in transformations. See Ogborn, J. (1985) Energy and Fuel: The meaning of the 'go' of things. In: Energy Matters, University of Leeds.

11. The teaching strategies used in the schemes are discussed in detail in Needham, R. in association with Hill, P. (1987) Teaching Strategies for developing understanding in science. University of Leeds.

12. The National Writing Project can be contacted at:

    National Writing Project
    Newcombe House
    45 Notting Hill Gate
    London W1 3JB

13. Important links can be made between the energy schemes and CLISP teaching materials developed for use in other topic areas: Plant Nutrition and Particulate Theory of Matter.

14. Millar, R. and Driver, R. (1987) Beyond Processes. Studies in Science Education, January 1987.

15. An analysis of students' ideas about plants and food can be found in Bell, B. and Brook, A. (1984) Aspects of secondary students' understanding of plant nutrition: full report. University of Leeds.

Further reading

On views of learning:

Osborne, R. and Freyberg, P. (1985) Learning in Science. The Implications of Children's Science. Heinemann. Auckland, New Zealand.

Bentley, D. and Watts, M. (1984) Some Ideas of Learning in the Area of Science Education. A workshop pack. Secondary Science Curriculum Review, 1984

Driver, R. (1983) The Pupil as Scientist? Open University Press, Milton Keynes.

On children's ideas:

Children's Learning in Science Project full reports: Aspects of Secondary Students' Understanding of: Particulate Nature of Matter (1984), Heat (1984), Plant Nutrition (1984), Energy (1984) Elementary Chemistry (1986). University of Leeds.

Driver, R., Guesne, E. and Tiberghien, A. (1986) Children's Ideas in Science. Open University Press, Milton Keynes.

On the energy concept:

Driver, R. and Millar, R. (eds.) (1985) Energy Matters. University of Leeds.

Wiser, M. and Carey, S. (1983) When Heat and Temperature Were One. In: Gentner, D. and Stevens, A.L. Mental Models. Lawrence Erlbaum Associates, New Jersey, U.S.A.